State of California
THE RESOURCES AGENCY
Department of Water Resources

BULLETIN No. 135

MADERA AREA INVESTIGATION

Preliminary Edition

AUGUST 1966

HUGO FISHER
Administrator
The Resources Agency

EDMUND G. BROWN
Governor
State of California

WILLIAM E. WARNE
Director
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FOREWORD

The 1960 Legislature authorized the funds for the Madera Area Investigation. This type of investigation by the Department of Water Resources is sanctioned by State Water Code Sections 12616 and 12617. The Madera Area Investigation was conducted to determine the water supply available to the Madera area, to determine the water requirements for continued development of the area, and to plan for the optimum development of all local supplies for maximum beneficial use. The study was begun in March 1961 and was completed in June 1965.

The investigation has shown that additional water will have to be imported to ensure continued economic growth of the area between now and the year 2020. The valley portion of the area can be supplied by the East Side Division of the Central Valley Project proposed by the U. S. Bureau of Reclamation. The upper Madera area must be supplied from locally developed water projects.

The Department of Water Resources recommends study of the proposed Oakhurst-Soquel Project to support the residential growth of the upper Madera area and for recreation and fishery enhancement. The Department also recommends study of the Upper San Joaquin River Project to provide hydroelectric power, recreation, fisheries enhancement, and irrigation.

William E. Warne

William E. Warne, Director
Department of Water Resources
The Resources Agency
State of California
June 22, 1966

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California State Department of Parks and Recreation

County of Madera

Madera Irrigation District

Chowchilla Water District

Pacific Gas and Electric Company

Southern California Edison Company

ABSTRACT

Bulletin No. 135
Madera Area Investigation
Preliminary Edition

The Madera area (all of Madera County and those portions of the drainage basins of the Chowchilla and Fresno Rivers which lie within Mariposa County) needs more water than can be provided by existing and authorized* projects. If present agricultural trends in the San Joaquin Valley continue, an estimated 200,000 acre-feet of supplemental water will be needed annually by the year 2020. In the upper Madera area, the economic demand for supplemental water will be about 7,600 acre-feet annually by the year 2020.

For the Valley, the logical source of supplemental water is the East Side Division of the Central Valley Project proposed by the U. S. Bureau of Reclamation.

The Oakhurst-Soquel Project would supply sufficient water to major areas of residential growth in the foothill and mountainous portions of the Madera area. The project would also provide significant recreation and fishery enhancement benefits. This project would include an earthfill dam and an 8,000 acre-foot reservoir on North Fork Willow Creek near Soquel Meadow. Development of this project, however, would require an exchange agreement with the Madera Irrigation District to obtain the requisite water rights.

The Upper San Joaquin River Project would provide power, recreation, and fisheries enhancement in the portion of upper Madera County that is tributary to Mammoth Pool Reservoir--the area from Chiquito Creek to the North Fork San Joaquin River. The project would also conserve additional water for irrigation in the Valley. This project would have a generating capacity of 191,000 kilowatts and would produce an annual average of 851 million kilowatt-hours of hydroelectric power.

*Two new water development projects in the Madera area have been authorized by Congress for construction by the U. S. Army Corps of Engineers. Hidden Dam on the Fresno River about 13 miles northeast of Madera would impound 90,000 acre-feet of water for flood control, water conservation, and recreation. Buchanan Dam on the Chowchilla River about 16 miles northeast of Chowchilla would form a 150,000 acre-foot reservoir for flood control, irrigation, recreation, and fish and wildlife.

CHAPTER I. INTRODUCTION

Madera -- meaning, in Spanish, "place of wood" -- has been aptly named. One of the most important industries in the upper Madera area since before the turn of the century has been lumbering. The name "Madera" was given to the site of the terminus of a 62-mile flume that transported lumber from the mountain mills to the railroad on the valley floor. Subsequently this community became both a city and the county seat.

The Madera Area Investigation was undertaken to fulfill the need for a comprehensive report on the water resources of the Madera area. The water requirements for the valley floor portion of Madera County previously had been determined by the U. S. Bureau of Reclamation for its Central Valley Project; however, no detailed studies had been made which integrated the data on water supplies, requirements, and related problems for the mountainous, foothill, and valley areas.

Hydrologic studies indicate that if the valley floor portion of the Madera area received its full contractual amount of Central Valley Project water and that if the Hidden and Buchanan Projects were constructed and operated as proposed, a hydrologic balance would exist with water requirements as they were in 1960. Increasing requirements have already rendered the Madera area water deficient, and this deficiency is expected to increase to about 200,000 acre-feet annually by the year 2020. Water will have to be imported to assure continued economic growth of the area. The logical source of supplemental water is the East Side Division of the Central Valley Project.

In the Upper Madera area, water supplies now are derived almost entirely from limited ground water resources. The wells are expensive, the yields are small and there is danger of pollution. Ground water supplies are inadequate to cope with increasing requirements and surface water supplies must be developed. This development should be on an area-wide basis because individual development is uneconomical and impractical.

The "Oakhurst-Soquel Project" proposed in this report is considered the most advantageous source of water supply for the Upper Madera area. A single reservoir, located near Soquel Meadow, could provide an outstanding recreation potential and an economical water supply to the Oakhurst, Ahwahnee, Coarsegold, Bass Lake, North Fork, and South Fork areas.

Another project proposed in this report is the "Upper San Joaquin River Project" located in the Minarets District of the Sierra National Forest. Project purposes include power, recreation, fish enhancement, and conservation. Major features of the project include four storage reservoirs with a combined gross capacity of 221,000 acre-feet, approximately 17 miles of tunnels and pipelines, and powerplants with an aggregate installed capacity of 191,000 kilowatts. The project would have a significant beneficial effect on the economy of the Madera area.

Background of Investigation

The Madera County Board of Supervisors, recognizing the inadequacy of local water supplies, appointed a Madera County Water Commission in 1958 to act as an advisory group to the Board. The Commission was requested to recommend a course of action to cope with water problems in the County. Shortly after the Commission was formed, it recommended that appropriate steps be taken to obtain authorization for a comprehensive water resources investigation of Madera County by the State Department of Water Resources.

The Department of Water Resources had previously conducted a series of investigations of the mountainous and foothill areas of the Sierra Nevada. These investigations were initiated to provide the basis for continued development in the upper watershed areas consistent with utilization of the available water supplies for demands in the valley areas. The investigations enabled local interests, both upstream and down, to evaluate proposed developments of water resources from an areawide point of view.

As a result of several meetings between Department personnel and Commission members an areawide water resources investigation of the Madera area was proposed. Funds were provided in the 1960-61 budget to start the investigation. It was scheduled to begin in January 1961, but a shortage of personnel and a limitation of available funds required that the actual starting date be postponed to March 1961 and the completion date extended from June 1964 to June 1965.

Authorization for the type of investigation conducted for Madera area is contained in State Water Code Sections 12616 and 12617.

Objective and Scope of Investigation

The objective of the Madera Area Investigation was to formulate a general plan for the development of the water resources of the valley floor and upper area of Madera County, to serve as a guide for local agencies in further planning for the development of local water resources to meet increasing needs. Achievement of this objective necessitated the evaluation of available water supply, present and future water requirements, study of possible plans for development of local water supplies, and consideration of the several major projects which are proposed for construction by federal agencies. The areawide concept of water development should include provision for maximum use of local and imported water supplies and development of rapidly expanding water-related recreation activities and flood control.

Related Investigations

The Madera Area Investigation included review of several prior investigations and reports. Of major importance are the following recent investigations and reports of the Department of Water Resources, the U. S. Army Corps of Engineers, and the U. S. Bureau of Reclamation. Results of other related investigations may be found in references listed in the Bibliography.

Statewide Water Resources Investigation

In recognition of the growing statewide water problems, the Legislature, by Chapter 1541, Statutes of 1947, authorized the Statewide Water Resources Investigation. This investigation was conducted by the Division of Water Resources, under the direction of the State Water Resources Board. Funds were appropriated annually by the Legislature over a 10-year period for the completion of this important program of study. Results of this investigation were published in three bulletins:

- Bulletin No. 1, "Water Resources of California", published in 1951, contains a compilation of data on precipitation, unimpaired streamflow, flood flows and frequencies, and quality of water.

- Bulletin No. 2, "Water Utilization and Requirements of California", published in 1955, sets forth estimates of present and probable ultimate water requirements throughout the State. In general, such estimates and forecasts are based on the capabilities of the land to support further development.

- Bulletin No. 3, "The California Water Plan", published in 1957, reports the third and concluding phase of the Statewide Water Resources Investigation. The California Water Plan is a comprehensive master plan for the development of the water resources of the State to meet, so far as is practicable, present and future needs for all beneficial purposes in all parts of the State. The Legislature, by enactment of Chapter 2053, Statutes of 1959, adopted The California Water Plan as a general guide for the orderly and coordinated development and use of the water resources of the State.

U. S. Army Corps of Engineers, "Fresno River Basin, California", report contained in Senate Document No. 37, 87th Congress, 1st Session

.This report presents a plan for the solution of the flood problems of the Fresno River Basin and for furnishing a supplemental water supply to the service area. The plan of improvement described in the report consists of a multiple-purpose reservoir at the Hidden site, with a capacity of 90,000 acre-feet, and supplemental downstream channel improvements.

U. S. Army Corps of Engineers, "Chowchilla River Basin, California", report contained in Senate Document No. 98, 87th Congress, 2nd Session.

This report presents a plan which will alleviate a serious flood problem in the Chowchilla River Basin, provide supplemental water supplies, and provide additional outdoor recreation opportunities. The plan of improvement described in the report consists of a multiple-purpose reservoir at the Buchanan site with a storage capacity of 150,000 acre-feet and supplemental downstream channel improvements.

U. S. Bureau of Reclamation, "East Side Division, Central Valley Project, California"--a Report on the Feasibility of Water Supply Developments--January 1962.

This report describes the feasibility of a project which will furnish supplemental water to the east side of the San Joaquin Valley. Water developed in the northern portion of the Valley would be transferred to areas of deficiency from the vicinity of Merced to Bakersfield.

Area of Investigation

The Madera area is located about midway between the Oregon and Mexican borders of California. It extends from the trough of the Great Central Valley on the San Joaquin River to the crest of the Sierra Nevada, a distance of about 110 miles in its longest dimension. It averages about 20 miles in width. A point near O'Neals in Madera County is reported to be the geographic center of California.

The area of investigation encompasses all of Madera County and the drainage area of the Fresno River Basin and the Chowchilla River Basin above the valley floor as shown on Plate 1, "Units of the Investigative Area". The area includes about 1,377,000 acres in Madera County and approximately 128,000 acres in Mariposa County in the Chowchilla and Fresno River Basins. About 380,000 acres of the Sierra National Forest lie within the area of investigation as do about 77,700 acres of Yosemite National Park and the 1,000-acre Devils Postpile National Monument. These public lands encompass almost the entire watershed above an elevation of 3,000 feet.

Natural Features

Elevations in Madera County range from a low of about 130 feet above sea level at the extreme northwestern corner of the County to 13,159 feet at the peak of Mount Ritter near the crest of the Sierra Nevada. The County may be nearly equally divided into valley plains (130 to 400 feet elevation), foothills (400 to 4,000 feet elevation), and high mountains (4,000 to 13,000 feet elevation).

In the valley plains portion of the area the natural semidesert landscape has given way to cattle grazing, intensive irrigated agriculture, and dry farming. The southwestern portion of the foothill zone is predominantly grassland, interspersed with dry-farmed grain crops. The central portion of this zone (to about 3,000 feet elevation) has a woodland-grass cover and is devoted primarily to range-livestock production. Above 3,000 feet and extending to nearly 8,000 feet in elevation is found the merchantable timber belt. Above 8,000 feet is found a second belt of forest, composed of noncommercial conifers. These trees are progressively more dwarfed and sparse as the crest of the Sierra Nevada is approached and as the terrain becomes more and more unweathered granitic and metamorphic rock.

Two major and two minor river systems drain the Madera Area. Of the major streams, Merced River tributaries rise in the Yosemite National Park portion of the area and flow out of the area in a westerly direction at a minimum elevation of about 5,000 feet. The other major system, the San Joaquin River, drains the remainder of the high elevation (above 7,000 feet) watershed together with the southeastern part of the lower areas. The river is the southwestern and western boundary of the area of investigation from Mammoth Pool to the Madera-Merced County line.

The two minor stream systems are the Fresno and Chowchilla Rivers which drain the central and northwestern portions of the area, respectively. Both of these streams are tributary to the San Joaquin River on the valley floor.

Geology

The San Joaquin Valley, which comprises approximately the southern two-thirds of the Great Valley of California, is a broad structural trough filled with an accumulation of sediments eroded from the surrounding highlands by rivers and streams. Approximately the western third of Madera County lies within the San Joaquin Valley between 120 and 450 feet above sea level. This portion is bounded on the south and west by the San Joaquin River and on the north by the Chowchilla River. To the east it merges into the Sierra foothills. The sedimentary deposits in the Valley occur principally as (1) old alluvium in the form of terraces in the dissected uplands along the eastern fringe of the Valley, (2) alluvial fans splaying out from streams as they emerge from the Sierra foothills, and (3) basin deposits along the axial trough of the Valley and interfan areas.

The San Joaquin Valley abuts the foothills of the Sierra Nevada at about the 400-foot elevation. Trending northwest along middle-eastern California, the Sierra Nevada is a complex of metamorphic and intrusive igneous rocks comprising a great fault-block about 400 miles long and 50 to 70 miles wide. This great fault-block has been tilted up on the east, attaining a maximum elevation of 14,496 feet at Mount Whitney, and down on the west where the block dips under the alluvial fill of the Great Valley. The northwest-trending, folded and faulted metamorphic rocks, a result of earlier diastrophism, were intruded by a copious quantity of granitic magma during the Late Jurassic and Early Cretaceous periods. In the Late Cretaceous and early Tertiary periods, erosion reduced the Sierra Nevada to an area of low relief. Then during the late Tertiary period, portions of the province were covered by a blanket-like mantle of sediments and volcanic rocks, the latter in the form of lava flows, airborne debris, and mudflows. Faulting, which has tilted and uplifted the Sierran Block, began in the Tertiary period and has continued to the present. This tilting of the Sierran Block has formed a high, steep fault-like scarp on the eastern face and has rejuvenated the streams which consequently cut deep canyons into the otherwise gentle western slope. Many of the streams have eroded the Tertiary sediments and volcanic rocks and have cut deeply into the underlying metamorphic and granitic rocks. Additional sculpturing toward the crest of the range and higher canyons was accomplished by Alpine glaciers in the Pleistocene epoch. The glacial action modified the topography by depositing glacial moraines and carving U-shaped canyons exemplified by Yosemite Valley.

In Madera County, erosion since the tilt-block faulting has reduced the Sierran western slope and exposed vast portions of granitic rock with only minor erosional remnants and roof pendants of metamorphic rocks. These erosional remnants are exposed mainly along the Sierra foothills and the Ritter Range. Nearly all of the Tertiary sediments and volcanic rocks were also eroded. Local remnants exist near Friant and along the Sierran crest.

Climate

The climate is varied since it is modified both locally and generally by topographical influences. The entire area is characterized by dry summers and mild winters. Normal summer temperatures in the lower foothills, however, are not only higher than those in the mountains, but higher than those prevailing on the valley floor. This apparent anomaly results from the existence of a static stratum of air in the foothills during the summer season.

Average annual precipitation on the Madera area varies from about 10 inches on the valley floor to over 55 inches along the crest of the Sierra Nevada. Precipitation varies widely from season to season and increases generally from west to east with an increase in land elevations. During winter, the Valley and lower foothill areas receive moderate amounts of rainfall and may have persistent fog, while the mountain zone receives heavy precipitation. Usually, precipitation below an elevation of about 3,500 feet occurs as rain, whereas above that elevation it falls as rain or snow, with an increasing incidence of snow at increasing elevations.

Soils

The soils of the Madera area are described in four groups based on natural divisions generally increasing in elevation from west to east. These groups are the recent and young alluvial deposits adjacent to the San Joaquin River, the basin rim, the alluvial fans, and the uplands.

The soils of the recent and young alluvial deposits adjacent to the San Joaquin River channel, in the trough of the Great Central Valley, were deposited during frequent floods and are deep, but under natural conditions they are usually poorly drained. Portions of the area have a high water table due to seepage from canals and the river channel. Flooding has been largely controlled with the construction of upstream dams and a system of levees along the river channel. These soils are successfully farmed where adequate drainage is provided.

The basin rim is the broad, very gently sloping plain at the lower end of the alluvial fans lying just above the recent alluvial deposits adjacent to the river channel. This area is characterized by hardpan soils developed under conditions of poor surface drainage and high water table which gave rise to accumulations of soluble salts and exchangeable sodium in the soil. A general lowering of the water table due to irrigation pumping in adjacent areas has enhanced the possibilities of reclaiming these soils. They may be reclaimed by breaking up the hardpan with deep tillage, adding appropriate soil amendments to replace the exchangeable sodium, and then leaching to remove the excess salts.

The alluvial fans consist of depositions of granitic sediments of different ages. The soils of the younger fans are deep and well drained and are the most intensively farmed soils in the area. They are lower than the more mature soils and have been formed by relatively recent deposits of sediments carried by the streams now dissecting the higher areas. They are generally suited for all climatically adapted crops.

The older and higher portions are dissected by the streams bearing the material which is forming the younger fans. The mature soils, developed on the higher and older parts of the alluvial fan, are characterized by restricting subsoil layers of claypan and hardpan which dominate in determining their use and management. Most of the hardpan subsoils could be broken up by deep tillage. Generally, cost has precluded this practice. Dry-farmed grain is the major use of the older soils. Summer fallowing is practiced in alternate years.

Soils in the uplands are termed "residual" because they have been formed in place by weathering of parent rock. Climate, topography, and resistance to weathering of the parent rock are the most significant factors in determining the characteristics of these soils, while age is of secondary importance.

The foothill soils are generally shallower than those of the higher mountains because they receive less rainfall and are formed on harder rock formations. These soils are used for range and dry-farmed grain. The steeper slopes are limited to range because of the shallowness and erodibility of the soils and occurrence of bedrock outcrops.

The more humid climatic conditions and softer rock formations of the higher mountains have produced deeper soils.

The deep, excellent timber site soils occur on the gentler slopes. These soils are used chiefly for watershed and production of timber. Summer grazing is the major use of the numerous alluvial grassy meadows.

Economic Development

The Madera area, during the 1870's, began to take on the characteristics of a diversified and well-established economy. The Central Pacific Railroad was extended through the valley floor, the California Lumber Company constructed a flume to convey lumber from the mills in the mountains to a rail terminus where the town of Madera was established, and a stagecoach line began to provide transportation between the newly established town and Yosemite Park at Wawona. Gold mining was rejuvenated to some extent, with interest switching from placer to lode deposits in the vicinities of Coarsegold, Oakhurst, Grub Gulch, Quartz Mountain, and several other communities in the lower mountain zone. The strong intertie between the upper and lower areas enhanced the economic growth of the Madera area, and in 1893 Madera County was formed from a portion of northern Fresno County.

Following the years of the national economic depression during the early 1930's the Madera area experienced a shift in the basic type of enterprises profitable for development. The formerly expanding mining and lumbering activities began to decline at a rate faster than the expansion of previous years. The adaptability of the upper Madera area for recreation activities was discovered by many people about this time, however, and provided a new basis for the continued economic growth of the area. Statistics are lacking on the extent of recreation prior to the 1940's, but by 1941 forest-based recreation alone provided 600,000 visitor-days of enjoyment within the Madera County portion of Sierra National Forest.

Water-associated recreation in the upper Madera area prior to 1941 was concentrated at Bass Lake, then known as Crane Valley Storage, owned by the Pacific Gas and Electric Company. The Forest Service maintains public campgrounds at Bass Lake and these have become overcrowded during the peak of the recreation season. The creation of Millerton Lake by the U. S. Bureau of Reclamation provided added water-associated recreation facilities at the foothill line of the Madera area. These facilities began to accommodate visitors during 1941; since then they have been enlarged, and during the 1963-64 recreation season they provided an estimated 554,000 visitor-days of recreation use.

During recent years the general Oakhurst vicinity of upper Madera area has experienced phenomenal growth of both recreation and year-round homes. The increase in permanent residents is attributed to employment in recreation-associated industries and the influx of people with retirement incomes. The concentration of residents near Oakhurst has created a need for community water and sewage systems.

The predominant industry of Madera County is agriculture. In 1963 the County ranked 17 in agriculture among the 58 California counties, with a gross agricultural return of $72 million. This industry is based mostly on the ability to irrigate about 230,000 acres in the valley floor portion of the County. The livestock industry is no longer based on the summer range of the upper Madera area. Significant numbers of cattle are accommodated by Sierra National Forest; however, they depend on the irrigation of valley pastures from deep wells and supplemental surface water supplies. The completion of Friant Dam in 1947 and the construction of the Madera Canal in 1948 provided a much broader base for agricultural production through the development of additional surface water supplies. The Madera Irrigation District and Chowchilla Water District provide irrigation service to the most productive lands of the County; however, significant amounts of irrigable lands remain undeveloped.

CHAPTER II. WATER SUPPLY

The available water supplies in the Madera area occur as surface runoff in the Chowchilla, Fresno, and San Joaquin River watersheds; surface runoff in intervening foothill watersheds; extractions from the ground; and direct precipitation. Under natural conditions, melting snow from the mountains provides most of the surface runoff during late spring and early summer. Surface runoff is regulated in reservoirs, notably Millerton Lake on the San Joaquin River, and released into natural channels or man-made conduits for use where most needed.

During the investigation a study was made of the water supplies available during a specific base period, as well as during the expected long-term future. These studies were made to facilitate an evaluation of the ground water supplies in the valley floor portion of Madera County. The future water supplies of the Madera area, which will include extractions from the ground, have been estimated from the information developed during the study.

Definitions

The following terms are defined as used in this bulletin in the discussion of water supply:

Precipitation Year - The 12-month period from July 1 of a given year through June 30 of the following year.

Runoff Year or Water Year - The 12-month period from October 1 of a given year through September 30 of the following year.

Historical Runoff - The flow of a stream as it has occurred during some past period of time, including the effects of prior upstream developments.

Natural Runoff - The flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development.

Impaired Runoff - The flow of a stream as it would be under any given state of upstream development.

Mean Period - A period chosen to represent conditions of water supply and climate over a long series of years.

Base Period - A period chosen for detailed hydrologic analysis because prevailing conditions of water supply and climate were approximately equivalent to mean conditions and because adequate data for such hydrologic analysis were available.

Mean - The arithmetic average relating to a mean period.

Average - The arithmetic average relating to other than a mean period.

Long-term Mean Future Water Supply - The mean period water supply adjusted for estimated future conditions.

Ground Water Overdraft - The rate of net seasonal extraction of water from a ground water basin in excess of the mean seasonal replenishment to the basin. One or both of the following conditions must also exist.

1. Water levels are not so lowered as to cause harmful impairment of the quality of the ground water by intrusion of other water of undesirable quality, or by accumulation and concentration of pollutants or degrading agents.

2. Water levels are not so lowered as to imperil the economy of ground water users by excessive costs of pumping, or by exclusion of users from a supply therefrom.

In studies for the Madera area, conditions during the 50-year period 1907-08 through 1956-57, inclusive, were considered representative of mean conditions of precipitation and runoff.

The six-year historic period from April 1952 through March 1958, inclusive, was selected as the base period because it was a period in which all the items of supply and disposal could be evaluated. In addition, it was fairly representative of the mean period, inasmuch as the runoff of the major streams having their headwaters in the area was 102 percent of the mean and precipitation on the valley floor was 113 percent of the mean.

Precipitation

During winter and spring, storms periodically sweep in from the north Pacific Ocean over the area of investigation. Precipitation from these storms is generally light in the lower valley areas and moderately heavy near the crest of the Sierra Nevada. The wide range of elevation and topography have pronounced effects on the amount of precipitation and whether it falls as rain or snow. Average annual precipitation ranges from about 10 inches on the valley floor to about 55 inches along the crest of the Sierra Nevada.

Precipitation Stations and Records

Continuous records of precipitation of ten or more years duration have been gathered for 33 stations in or near the area. Additional stations have shorter periods of record. The station at Friant has the longest period of record, extending from 1897 to the present time. Table 1 presents the locations; elevations; periods and sources of record; and mean, maximum, and minimum precipitation for selected stations. The stations are distributed areally from the trough of the Valley at Chowchilla Farms (elevation 150 feet) to the crest of the Sierra Nevada at Mammoth Pass (elevation 9,500 feet). As noted in Table 1, certain of the records have been extended to cover the 50-year mean period by direct correlation with records of nearby and/or similarly located stations.

Eighteen snow courses which lie in or near the Madera area are measured and maintained as part of the California Cooperative Snow Surveys. All of these courses lie above an elevation of 6,500 feet. Eleven courses are in the San Joaquin River Basin, two are in the Merced River Basin, two are in the Mono Lake Basin, and three are in the Owens River Basin. Regular measurements at these stations provide valuable information regarding the precipitation in the upper watersheds of these rivers and for forecasting the spring and summer runoff from snowmelt. Table 2 presents the location; elevation; period of record; and average, maximum, and mean water content of snow on April 1 for these snow courses. Because very few snow course records antedate 1930, the period of record used to determine average values is 1930-31 through 1959-60.

Precipitation Characteristics

Precipitation varies widely from place to place, from season to season, and from year to year. From the valley floor to the crest of the Sierra Nevada, precipitation generally varies directly with change in elevation; that is,

TABLE 1

MEAN, MAXIMUM, AND MINIMUM ANNUAL PRECIPITATION
AT SELECTED STATIONS IN OR NEAR
MADERA AREA

Station	General Location				Elevation in Feet	Source of Record*	Period of Record	Estimated or Recorded Mean Annual Precipitation in Inches	Maximum and Minimum Annual Precipitation	
	County	Township	Range	Section					Year	Inches
Ahwahnee	Madera	6S	21E	31	2,323	USWB	1949-59	29.35^{c}	1955-56 1949-50	38.70 21.25
Ahwahnee 2NNW	Madera	6S	20E	24	2,790	USWB	1959-present	---	1962-63 1960-61	29.77 18.87
Ahwahnee Sanatorium	Madera	6S	21E	25	2,360	U.C. at Davis	1950-58	27.59^{c}	1955-56 1952-53	42.33 21.93
Athlone	Merced	8S	15E	29	210	USWB	1885-98	11.57^{c}	1889-90 1897-98	19.07 6.47
Auberry	Fresno	10S	23E	8	2,003	USWB	1915-present	24.50^{c}	1937-38 1923-24	45.02 13.64
Bass Lake	Madera	7S	22E	23	3,300	USWB	1934-45	44.17^{c}	1940-41 1943-44	59.94 37.51
Berenda S.P.R.R.	Madera	10S	17E	30	256	USWB	1889-1900	10.11^{c}	1889-90 1899-1900	16.46 8.12
Big Creek PH #1	Fresno	8S	25E	28	4,930	USWB	1913-present	31.12^{c}	1937-38 1923-24	53.68 15.86
Big Creek PH #2	Fresno	8S	24E	25	3,000	SCE	1913-present	30.90^{c}	1937-38 1923-24	51.98 14.92
Big Creek PH #3	Fresno	9S	24E	17	1,400	SCE	1922-present	25.91^{c}	1937-38 1923-24	45.43 11.53
Big Creek PH #4	Fresno	9S	23E	20	1,000	SCE	1951-58	23.25^{c}	1955-56 1956-57	36.93 18.88
Big Creek PH #8	Fresno	8S	24E	27	2,260	SCE	1921-present	27.36^{c}	1937-38 1923-24	47.25 14.39

TABLE 1 (Continued)

MEAN, MAXIMUM, AND MINIMUM ANNUAL PRECIPITATION
AT SELECTED STATIONS IN OR NEAR
MADERA AREA

Station	General Location				Elevation in Feet	Source of Record*	Period of Record	Estimated or Recorded Mean Annual Precipitation in Inches	Maximum and Minimum Annual Precipitation	
	County	Township	Range	Section					Year	Inches
Central Camp	Madera	7S	24E	5	5,364	USWB	1940-48	48.03[c]	1942-43 1943-44	66.55 34.98
Chowchilla Farms	Madera	10S	14E	8	150	Private Observer	1887-1913 1916-38	8.74[c]	1905-06 1923-24	18.42 4.23
Clover Meadows G. S.	Madera	5S	25E	6	7,002	DWR	1946-present	41.95[c]	1955-56 1960-61	64.50 30.13
Coarsegold	Madera	8S	21E	5	2,240	USWB	1947-present	27.72[c]	1951-52 1958-59	46.82 17.35
Crane Valley PH	Madera	7S	22E	25	3,500	P. G. & E.	1903-present	40.45[r]	1937-38 1923-24	69.39 18.37
Crane Valley 3WNW	Madera	7S	22E	20	3,660	Private Observer	1949-61	39.91[c]	1957-58 1960-61	61.77 25.65
Daulton	Madera	9S	18E	26	410	Private Observer	1946-present	13.00[c]	1957-58 1946-47	26.71 6.46
Denair	Stanislaus	5S	11E	6	124	USWB	1899-present	12.24[c]	1957-58 1923-24	21.41 5.07
Fish Camp	Mariposa	5S	21E	26	5,550	Private Observer	1929-33	47.94[c]	1931-32 1932-33	50.89 24.10
Florence Lake	Fresno	7S	27E	36	7,345	USWB	1940-present	24.14[c]	1955-56 1948-49	53.76 15.84
Friant Government Camp	Fresno	11S	21E	7	410	USWB	1897-present	13.41[r]	1957-58 1897-98	22.67 5.91
Huntington Lake	Fresno	8S	25E	22	7,020	SCE & USWB	1912-present	31.31[c]	1955-56 1923-24	54.01 15.70
LeGrand Preston Ranch	Mariposa	7S	18E	7	984	Private Observer	1949-present	17.75[c]	1951-52 1958-59	28.20 12.10

TABLE 1 (Continued)

MEAN, MAXIMUM, AND MINIMUM ANNUAL PRECIPITATION
AT SELECTED STATIONS IN OR NEAR
MADERA AREA

Station	General Location				Elevation in Feet	Source of Record*	Period of Record	Estimated or Recorded Mean Annual Precipitation in Inches	Maximum and Minimum Annual Precipitation	
	County	Township	Range	Section					Year	Inches
LeGrand	Merced	8S	16E	20	255	USWB	1899-present	12.49[r]	1957-58 1907-08	22.58 4.87
LeGrand Turner Ranch	Mariposa	7S	17E	24	840	Private Observer	1953-61	17.25[c]	1957-58 1958-59	26.90 10.38
Logan Meadows	Madera	7S	24E	11	3,400	USWB	1948-present	30.97[c]	1955-56 1952-53	48.62 21.81
Madera	Madera	11S	17E	13	270	USWB	1899-present	10.01[r]	1940-41 1923-24	19.77 5.49
Mammoth Pass	Mono	3S	26E		9,500	USWB	1947-present	58.27[r]	1951-52 1959-60	84.60 35.29
Meadow Lake	Fresno	10S	23E	11	4,485	USWB	1948-present	29.46[c]	1951-52 1960-61	42.42 20.33
North Fork R. S.	Madera	8S	23E	18	2,630	USWB	1904-present	33.08[r]	1908-09 1928-29	61.59 16.88
Ostrander Lake	Mariposa	3S	22E	34	8,600	DWR	1947-present	47.89[c]	1951-52 1960-61	68.84 31.00
Raymond 3SSW	Madera	9S	19E	6	635	Private Observer	1940-present	13.05[c]	1957-58 1948-49	27.85 7.45
Raymond Whipple Ranch	Mariposa	6S	19E	33	1,380	DWR	1957-62	23.93[c]	---	--- ---
Raymond 9N	Mariposa	7S	19E	3	1,210	DWR	1962-present	---	---	--- ---
Raymond 10N	Mariposa	6S	19E	32	1,640	Private Observer	1957-present	---	1957-58 1958-59	34.84 14.68

TABLE 1 (Continued)

MEAN, MAXIMUM, AND MINIMUM ANNUAL PRECIPITATION
AT SELECTED STATIONS IN OR NEAR
MADERA AREA

Station	General Location				Elevation in Feet	Source of Record*	Period of Record	Estimated or Recorded Mean Annual Precipitation in Inches	Maximum and Minimum Annual Precipitation	
	County	Township	Range	Section					Year	Inches
Raymond 12NNE	Mariposa	6S	19E	25	1,600	DWR	1954-present	25.62^c	1955-56 1958-59	41.00 13.32
San Joaquin Exp. Range	Madera	10S	21E	6	1,100	USWB	1934-present	17.64^c	1957-58 1958-59	32.07 10.11
South Entrance Y.N.P.	Mariposa	5S	21E	12	5,120	USWB	1941-present	44.10^c	1957-58 1946-47	64.64 24.92
Summerdale	Mariposa	5S	21E	23	5,270	USWB	1896-1912	47.94^c	1900-01 1897-98	85.46 29.54
Vignolo Ranch	Madera	8S	18E	33	440	Private Observer	1933-39	13.53^c	1934-35 1933-34	21.70 8.95
Westfall R. S.	Madera	5S	21E	35	4,795	Westfall R. S.	1958-present	---	1961-62 1960-61	47.81 28.95
Windy Gap	Madera	7S	20E	2	1,875	USBR	1952-55	---	---	--- ---

Legend

*USWB - United States Weather Bureau
P.G. & E. - Pacific Gas and Electric Company
U.C. at Davis - University of California, Davis Campus
SCE - Southern California Edison Company
DWR - California Department of Water Resources
Westfall R.S. - Westfall Ranger Station

--- Unable to calculate because of insufficient data

r - Based on 1905-06 to 1954-55 period
c - Corrected to 1905-06 to 1954-55 period

TABLE 2

SNOW COURSES
IN AND NEAR MADERA AREA

Snow Course	Latitude and Longitude	Elevation, in Feet	Year Record Began	Water Content of Snow on April 1: Average 1931-60 (inches)	Year: Max.	Year: Min.	Inches: Max.	Inches: Min.
MERCED RIVER BASIN								
Ostrander Lake	37°38.2' 119°33.0'	8,200	1937-38	34.1*	1952	1951	60.4	17.1
Peregoy Meadows	37°40.0' 119°37.5'	7,100	1930-31	32.9	1952	1934	79.5	14.3
SAN JOAQUIN RIVER BASIN								
Mammoth Pass	37°36.0' 119°02.0'	9,500	1927-28	42.3	1952	1931	75.7	15.5
Agnew Pass	37°43.6' 119°08.5'	9,450	1929-30	31.4	1952	1931	56.4	11.0
Cora Lakes	37°35.9' 119°16.0'	8,400	1938-39	37.5*	**	1961	61.7	18.2
Nellie Lake	37°15.4' 119°13.5'	8,000	1943-44	38.0*	1952	1951	76.6	17.5
Chilkoot Lake	37°24.5' 119°28.8'	7,450	1929-30	37.6	1952	1934	80.0	2.6
Chilkoot Meadow	37°24.6' 119°29.4'	7,200	1929-30	36.9	1952	1934	73.0	4.2
Clover Meadow	37°31.7' 119°16.5'	7,000	1938-39	23.6*	**	1963	38.7	5.7
Jackass Meadow	37°29.8' 119°19.8'	7,000	1938-39	23.9*	**	1951	59.9	5.0
Chiquito Creek	37°29.9' 119°24.5'	6,800	1938-39	22.4*	**	1951	40.0	5.2

TABLE 2 (Continued)

SNOW COURSES
IN AND NEAR MADERA AREA

Snow Course	Latitude and Longitude	Elevation, in Feet	Year Record Began	Water Content of Snow on April 1: Average 1931-60 (inches)	Year Max.	Year Min.	Inches Max.	Inches Min.
Beasore Meadows	37°26.5' 119°28.8'	6,800	1938-39	28.7*	1952	1963	66.1	4.9
Poison Meadow	37°23.8' 119°31.1'	6,800	1943-44	26.3*	1952	1947	67.9	3.4
MONO LAKE BASIN								
Gem Pass	37°46.8' 119°10.2'	10,400	1930-31	32.0	**	1931	51.2	7.8
Gem Lake	37°45.1' 119°09.7'	9,150	1926-27	31.3	**	1931	56.9	8.7
OWENS RIVER BASIN								
Minarets No. 2	37°39.8' 119°01.0'	9,000	1927-28	30.9	1952	1931	59.0	11.0
Minarets No. 1	37°39.0 118°49.5'	8,300	1927-28	20.2	1952	1934	45.5	4.0
Mammoth	37°37.2' 118°59.5'	8,300	1927-28	20.1	1952	1951	43.4	3.4

*Record extended to 1931-60 by correlation.
**Discontinuous Record--not measured in 1952.

the average precipitation increases from about 10 inches annually near the trough of the Valley to about 55 inches in the highest elevations. Precipitation below an elevation of about 3,500 feet generally occurs as rain and results in almost immediate runoff. Above this elevation the precipitation occurs as rain or snow. Much of the snow does not become runoff until late spring or summer. Lines of equal mean annual precipitation (in inches) are shown on Plate 2.

Annual precipitation at the Madera Station has varied from 55 to 197 percent of the mean. In the precipitation season of 1923-24 a total of only 5.49 inches was recorded, which is the minimum of record. The maximum annual precipitation recorded (19.77 inches) occurred during the season of 1940-41. At Bass Lake (Crane Valley Powerhouse Station) minimum and maximum recorded precipitation has ranged from 18.37 to 69.39 inches. These extremes occurred in 1923-24 and 1937-38, respectively, and represent 45 to 171 percent of the annual mean. Seventy to seventy-two percent of the precipitation occurs from December through March whereas only two to three percent occurs from June through September. Seasonal and cyclical variations in precipitation at Madera and Bass Lake (Crane Valley Powerhouse) are shown graphically on Plates 3A, 3B, 4A, and 4B which depict mean annual precipitation and accumulated departure from the mean at these stations. Table 3 shows average monthly distribution of precipitation at Madera and Bass Lake. The maximum recorded depth of precipitation in or near the Madera area occurred at Summerdale Station in 1900-01 when a total of 85.46 inches was measured. The maximum recorded snowpack in the area occurred in 1952 when a total of 80 inches of water content was measured at Chilkoot Meadow Station. Because of wide variations in elevation and precipitation, no single station is representative of the entire area; therefore, stations at Madera and Bass Lake (Crane Valley Powerhouse) were selected to show amounts of precipitation. Table 4 presents annual recorded precipitation at these stations.

Precipitation on the valley floor occurs as rainfall and in most areas averages less than 12 inches per year. For all practical purposes, this is considered the lower limit of precipitation below which no significant deep percolation occurs. Mean period precipitation figures were obtained from isohyetal maps and average 9.88 inches annually. Base period precipitation was related to mean precipitation by comparing precipitation at five stations distributed throughout the valley floor. Base period precipitation averaged 11.20 inches annually or 113.4 percent of the mean.

Runoff from direct precipitation on the valley floor unit was analyzed. The results are shown in Table 5 and are based on the assumption that when precipitation was greater than water surface evaporation (or evapotranspiration)

TABLE 3

AVERAGE MONTHLY DISTRIBUTION OF PRECIPITATION AT STATIONS IN MADERA AREA

Month	Precipitation, in Inches and Percent of Annual Total			
	Madera1/		Bass Lake2/ (Crane Valley P.H.)	
	Inches	Percent	Inches	Percent
July	.01	0.1	0.04	0.1
August	.01	0.1	0.042	0.1
September	0.10	1.0	0.63	1.6
October	0.45	4.5	1.57	3.9
November	0.96	9.6	3.22	8.1
December	1.58	15.7	6.67	16.7
January	1.91	19.0	8.10	20.2
February	1.91	19.0	7.62	19.1
March	1.67	16.7	6.58	16.4
April	0.97	9.7	3.52	8.8
May	0.41	4.1	1.72	4.3
June	0.05	0.5	0.30	0.7
TOTALS	10.03	100.0	40.01	100.0

1/ 64 years of record, elevation 270 feet.
2/ 60 years of record, elevation 3500 feet.

TABLE 4

RECORDED ANNUAL PRECIPITATION AT SELECTED STATIONS IN MADERA AREA
(in Inches)

Year	Madera	Crane Valley	Year	Madera	Crane Valley
1899-1900	9.30		1931-32	9.22	52.22
01	13.68		33	6.91	29.56
02	9.81		34	5.75	23.76
03	8.36		35	19.18	45.64
04	8.32	36.86	36	12.70	44.58
05	9.59	38.55	37	12.10	47.88
06	13.69	55.53	38	17.29	69.39
07	10.21	51.25	39	8.01	28.07
08	8.24	27.15			
09	6.83	53.37	1939-40	12.13	49.45
			41	19.77	56.06
1909-10	9.66	39.29	42	13.12	47.92
11	10.93	60.05	43	8.87	48.62
12	6.18	28.20	44	10.42	34.59
13	6.39	23.15	45	9.73	49.24
14	8.47	55.93	46	8.18	34.79
15	12.19	40.99	47	7.70	30.13
16	15.24	51.37	48	10.49	32.11
17	9.72	50.00	49	7.90	31.24
18	8.90	33.46			
19	7.98	35.13	1949-50	8.89	30.52
			51	11.23	46.51
1919-20	5.88	38.67	52	12.08	58.12
21	11.11	42.07	53	9.83	35.84
22	14.42	48.03	54	8.41	40.27
23	10.44	41.03	55	9.75	33.49
24	5.49	18.37	56	13.82	60.06
25	9.64	38.33	57	8.30	33.04
26	6.34	29.64	58	17.47	54.47
27	10.28	41.85	59	5.79	26.02
28	9.21	32.68			
29	9.18	29.22	1959-60	8.78	31.37
			61	8.83	23.50
1929-30	6.07	26.21	62	11.15	39.54
31	7.71	23.31	63	9.62	43.26

about 10 percent of the excess precipitation ran off and the remainder accrued to the soil until the soil reservoir was filled, at which point all further precipitation ran off.

TABLE 5

CONSUMPTIVE USE AND RUNOFF FROM PRECIPITATION ON VALLEY FLOOR UNIT OF MADERA AREA (in Thousands of Acre-feet per Year)

	Precipitation on Basin	Consumptive Use of Precipitation	Runoff from Precipitation
Base Period	510.4	498.6	11.8
Mean Period	450.3	442.1	8.2

Runoff

Over 98 percent of the entire runoff originating in the Madera area is derived from four river drainage basins lying either entirely or partially within the Madera area. These are basins of the San Joaquin, Merced, Fresno, and Chowchilla Rivers.

Approximately 45 percent of the 1,675-square-mile watershed of the San Joaquin River above the Friant Gaging Station lies within the Madera area and contributes about half of the 1,703,800 acre-feet mean annual natural runoff of the San Joaquin River at Friant. Consumptive use of the San Joaquin River water within the Madera area includes: water supplied to the Madera Irrigation District and the Chowchilla Water District via the Madera Canal under contracts with the U. S. Bureau of Reclamation; the Soquel Diversion which transfers water from the San Joaquin River Basin to the Fresno River (see "Interbasin Transfer of Water" in this chapter); surface and pump diversions from the river below Friant; recharge to ground water below Friant; and minor domestic use in the Upper Madera Unit.

About 154 square miles of the watershed of the Merced River lies within the Madera area. This portion of the Merced River watershed lies above 5,000 feet elevation and yields an estimated average of 200,000 acre-feet of runoff annually, of which an estimated average of 8,800 acre-feet annually is transferred to the Fresno River Basin by means of the Big Creek Diversion (see "Interbasin Transfer of Water" in this chapter) and is available for consumptive use within the Madera area.

The Fresno and Chowchilla River watersheds lie entirely within the Madera area and their entire runoff is available for consumptive use within the area. The runoff from these streams is considerably less than that from the portions of the San Joaquin River and the Merced River drainage basins within the Madera area. The 50-year mean annual natural runoff of the Fresno River near Daulton and the Chowchilla River at Buchanan Dam site is estimated to be 68,500 acre-feet and 73,940 acre-feet, respectively.

Foothill streams contribute a minor amount of streamflow to the Valley Floor Unit of the Madera area. The flows are intermittent and occur during periods of heavy rainfall.

Runoff Characteristics

Since surface runoff originates from precipitation, it also varies widely from season to season and from year to year. The yearly extremes in runoff are even more pronounced than yearly extremes in precipitation because water must saturate the soil mantle before runoff can occur. Much of the water absorbed by the soil is subsequently consumptively used by evapotranspiration from forest, meadows, and brush lands, the remaining portion eventually reaching the stream system as effluent seepage. The evapotranspiration rates are higher in the lower elevation watersheds and the precipitation is less, resulting in greater yearly extremes in runoff than from higher elevation watersheds. The yearly runoff from high altitude watersheds, such as the North Fork of the San Joaquin River, varies the least because of lower consumptive use and greater precipitation.

Runoff from the Merced River Basin and San Joaquin River Basin is derived for the most part from melting snow because the major portions of the watersheds lie above 5,000 feet in elevation, the approximate winter snowline. This causes runoff to lag precipitation and prolong the period of significant runoff into July.

The Fresno and Chowchilla Rivers, on the other hand, have comparatively low-altitude watersheds and most of the runoff is from rainfall. Streamflow diminishes rapidly after the precipitation season. During the summer the small streamflow is derived from effluent seepage, and during dry years there is no flow in the channels during late summer and fall.

Regulation of Streamflow

In the San Joaquin River Basin, the U. S. Bureau of Reclamation, the Southern California Edison Company, and the Pacific Gas and Electric Company own and operate storage dams and reservoirs which provide a moderate degree of regulation to the natural runoff. Bass Lake, a power reservoir of the Pacific Gas and Electric Company, lies entirely within the Madera area. Mammoth Pool Reservoir and Redinger Lake (power reservoirs of the Southern California Edison Company) and Millerton Lake (a multiple-purpose project for irrigation, flood control, recreation, and domestic water supply) lie on the Fresno-Madera County boundary. Southern California Edison Company's Dam No. 7 and Pacific Gas and Electric Company's Kerckhoff Dam also lie on the Fresno-Madera County boundary but the small amount of storage provides no significant regulation of streamflow.

The streamflow from the portion of the Merced River Basin lying within the Madera area is not regulated; moreover, it is unlikely that it will be in the future, as most of the watershed is in the Yosemite National Park.

At the present time, there is no significant regulation of the runoff of the Fresno and Chowchilla River Basins, and the water is used during the runoff season. This condition soon will change, however, with the construction of Hidden Dam on the Fresno River and Buchanan Dam on the Chowchilla River. The Buchanan Project, authorized by Congress for construction on the Chowchilla River, will consist of a dam creating a 150,000-acre-foot reservoir and appurtenant works to control floods on the river and to make an average of about 28,000 acre-feet of new water available for irrigation annually. On the Fresno River another authorized project consisting of Hidden Dam and Reservoir together with appurtenant works will prevent most of the flooding which has occurred in the past. Also it is estimated that on the average about 24,000 acre-feet of new water will be available annually for irrigation from the 90,000-acre-foot reservoir. Both reservoirs will provide opportunities and facilities for a large amount of water-oriented recreation.

Despite the existing and authorized water development projects on these streams, additional facilities can develop water supplies to meet the water requirements of the upper watershed of the area. Close coordination and cooperation between local agencies on the valley floor and those in the foothill and mountainous areas will be necessary to resolve conflicting requirements for and rights to these waters.

Stream Gaging Stations and Records

Records of streamflow for the main channels of the four drainage basins in the Madera area are generally of sufficient length of time, number, and accuracy for reliable hydrologic studies. Tributary streams where possible water development projects have been considered by various agencies do not all have records of the same duration. Many stations were operated for only short periods of time and were then abandoned, probably because they had served their purpose in determining the feasibility of using streamflow. Other stations having records during the 1920's were abandoned during the depression and World War II years and were then reactivated in the early 1950's. The stations maintained by the Department of Water Resources for this investigation and the Mariposa Area Investigation have been installed in recent years and have relatively short periods of record. Gaging stations on streams affected by power development on the San Joaquin River generally have been maintained from the time of project construction until now.

At or near the storage damsites and diversion damsites on the San Joaquin River tributaries considered for possible development (see Plate 19, "Plan of the Upper San Joaquin River Project"), records of streamflow were available for discontinuous periods with total lengths of about 20 years. Correlation of the flow of these stations with the natural flow of the San Joaquin River at Friant was very good; therefore, the runoff at these stations for the years when no records were available was estimated by such correlation.

The drainage area, period of record, and source of record for selected stream gaging stations in the Merced, San Joaquin, Chowchilla, and Fresno River Basins are shown in Table 6.

Merced River Basin

Records of runoff of the Merced River at or near Exchequer since 1901 are available. Flow of the Merced River at this station has been impaired by regulation in Lake McClure since 1926, and by a small diversion from Big Creek, a tributary of South Fork Merced River, by the Madera Irrigation District and its predecessors since the turn of the century. This diversion will be discussed in more detail in subsequent sections of the report. The natural flow of the Merced River at Exchequer was computed by adjusting the recorded runoff to remove the effects of man's regulation. Since the Exchequer station is at the base of the foothills and is not in the area of investigation, its value lies in providing a long-term record for correlation with and extension of the relatively short records of streamflow at other stations.

Variation in the runoff of the Merced River Basin is illustrated by the following statistics of the natural flow at Exchequer. The maximum annual runoff was 2,114,600 acre-feet or 224 percent of the 50-year mean and occurred in

TABLE 6

STREAM GAGING STATIONS
IN THE
MERCED, SAN JOAQUIN, CHOWCHILLA, AND FRESNO RIVER BASINS

Stream	Station	Drainage Area in Sq. Miles	Period of Record	Source* of Record
	MERCED RIVER BASIN			
ed River	At Exchequer	1,037.6	1901-**	USGS
ed River	At Pohono Bridge	321	1916-**	USGS
mite Creek	At Yosemite	42.7	1904-1926	USGS
ed River	At Yosemite	236	1904-1918	USGS
ya Creek	Near Yosemite	47	1904-1909 1912-1958	USGS
ed River	At Happy Isles Bridge	181	1915-**	USGS
louette Creek	Near Yosemite	60.5	1915-1916	USGS
ed River	Above Illilouette Creek	119	1915-1916	USGS
ed River, uth Fork	Near Wawona	132	1910-1922	USGS
ed River, uth Fork	At Wawona	100	1958-**	USGS
Creek	Near Wawona	--	1910-1913	USGS
	SAN JOAQUIN RIVER BASIN			
Joaquin River	Near Dos Palos	5,630	1941-1954	USBR
Joaquin River	Near Mendota	4,310	1939-1954	USBR
Joaquin River	At Whitehouse	--	1901-1962	DWR
Joaquin River	Near Biola	1,805	1952-1961	USGS
Joaquin River	Below Skaggs Bridge	--	1926-1935	DWR
Joaquin River	At Herndon	--	1891-1909	USGS
Joaquin River	Near Hamptonville	1,637	1878-1884	DWR
Joaquin River	Inflow to Millerton Lake	--	1941-**	DWR
Joaquin River	Below Friant	1,675	1907-**	USGS
Joaquin River	Millerton Lake at Friant	1,633	1941-**	USBR
Joaquin River	Near Friant	1,632	1907-1939	USGS
Joaquin River	Below Kerckhoff Power House	1,480	1936-1937 1942-**	SCE
Joaquin River	Near Auberry	1,462	1927-**	USGS
Joaquin River	Kerckhoff Reservoir	--	1931-**	PG&E
Joaquin River	Near North Fork	1,448	1910-1914	SCE
Joaquin River	Above Willow Creek	1,299	1951-**	SCE
nger Lake	Near Auberry	1,297	1950-**	SCE
Joaquin River	Above Big Creek	1,050	1912-**	SCE
Joaquin River	At Mammoth Pool	998	1905-**	DWR
Joaquin River	At Miller Crossing	254	1921-1928 1951-**	SCE
Joaquin River, rth Fork	Below Iron Creek	38	1920-1928 1950-**	SCE
Joaquin River, ith Fork	Near Hoffman Meadow	428	1921-1928	USGS
Joaquin River, ith Fork	Below Hooper Creek	177	1947-**	SCE
Joaquin River, ith Fork	Near Florence Lake	171	1921-**	SCE
ence Lake	Near Big Creek	171	1925-**	SCE
onwood Creek	Near Friant	38.0	1936-1951	USBR
Gold Creek	Near Friant	92.8	1936-1958	USGS
Sandy Creek	Near Auberry	27.8	1946-1951	USGS
ow Creek	At Mouth Near Auberry	130	1952-**	SCE
ow Creek, rth Fork	Near North Fork	31.1	1910-1911	PG&E
ow Creek, rth Fork	Near Bass Lake	50.8	1940-**	PG&E
ow Creek, ith Fork	Near North Fork	38.7	1910-1917	PG&E
Lake	Near Bass Lake	52.1	1911-**	PG&E
key Creek	Near North Fork	12.9	1910-1915	PG&E
idel Creek	Near North Fork	3.32	1910-1912	PG&E
enson Creek	At Shaver	31.5	1915-**	SCE
er Lake	Near Big Creek	29.1	1927-**	SCE
Creek	Near Mouth Near Big Creek	129	1923-1932	USGS
Creek	Below Huntington Lake	80.0	1925-**	SCE
ington Lake	Near Big Creek	79.0	1913-**	SCE
Creek	Near Big Creek	88.0	1910-1916	SCE

Stream	Station	Drainage Area in Sq. Miles	Period of Record	Source* of Record
	SAN JOAQUIN RIVER BASIN (continued)			
Pitman Creek	At Big Creek	23.5	1910-1928	USGS
Pitman Creek	Near Tamarack Mountain	22.0	1927-**	SCE
Pitman Creek	Below Tamarack Creek	22.7	1927-**	SCE
Chiquito Creek	Near Arnold Meadow	59.6	1921-1928 1951-1960	SCE
Chiquito Creek	Near Mugler Meadow	23.1	1923-1925	SCE
Jackass Creek, West Fork	Near Fullers Meadow	10.5	1924-1925	SCE
Jackass Creek	Near Fullers Meadow	23.5	1924-1925	SCE
Jackass Creek	Near Jackass Meadow	12.8	1921-1928 1951-**	SCE
Granite Creek	Near Cattle Mountain	47.8	1921-1928 1952-**	SCE
Granite Creek, East Fork	Near Cattle Mountain	14.8	1922-1925	SCE
Granite Creek, Middle Fork	Near Cattle Mountain	2.18	1922-1923	SCE
Granite Creek, West Fork	Near Timber Knob	26.4	1921-1928	USGS
Iron Creek	At Mouth	5.94	1922-1923	USGS
Mono Creek	Below Edison Lake	92.0	1921-**	SCE
Edison Lake	Near Big Creek	88.9	1954-**	SCE
Bear Creek	At Division Dam	53.0	1927-**	SCE
Bear Creek	Near Edison Lake	53.5	1921-**	SCE
Hooper Creek	At Diversion Dam	7.3	1946-**	SCE
	CHOWCHILLA BASIN			
Chowchilla River	Near Buchanan	268	1878-1884	DWR
Chowchilla River	At Buchanan Dam Site	235	1921-**	USGS
Chowchilla River	Near Raymond	204	1958-**	DWR
Chowchilla River, West Fork	Near Mariposa	33.6	1957-**	DWR
Chowchilla River, Middle Fork	Near Nipinnawassee	12.3	1958-**	DWR
Chowchilla River, East Fork	Near Ahwahnee	57.8	1957-**	DWR
Striped Rock Creek	Near Raymond	17.1	1957-**	DWR
	FRESNO RIVER BASIN			
Fresno River	Near Madera	--	1914-1923	DWR
Fresno River	At Base of Foothills	272	1878-1884	DWR
Fresno River	Near Daulton	259	1938-**	USGS
Fresno River	Near Knowles	133	1911-**	USGS
Dry Creek	Near Kismet	--	1944-1946	USBR
Miami Creek	Near Oakhurst	10.6	1959-**	DWR
Fresno River, North Fork, Miami Creek	Near Sugar Pine	--	1910-1913	USGS
Nelder Creek	Near Fresno Flats	13.6	1910-1912	USFS
Big Creek Diversion	Near Fish Camp	--	1958-**	DWR
Madera Canal and Irrigation Company Canal	Near Madera	--	1938-**	MID

* MID - Madera Irrigation District
USGS - United States Geological Survey
USBR - United States Bureau of Reclamation
USFS - United States Forest Service
DWR - Department of Water Resources
SCE - Southern California Edison Company
PG&E - Pacific Gas and Electric Company
**Record continues to present time (1965)

the 1910-11 runoff season. In 1923-24 the runoff amounted to only 252,200 acre-feet which is the minimum of record and only 27 percent of the 50-year mean. Actual observed discharge at this point has varied from no flow for part of November 21, 1901, to 47,700 second-feet on January 31, 1911.

Estimated mean annual natural runoff and monthly distribution of the Merced River at Exchequer is shown in Table 7.

Chowchilla River Basin

Streamflow records for the Chowchilla River and its East, West, and Middle Forks have been maintained for various periods since 1921. The natural runoff for the main stem at Buchanan Dam site for the missing periods of record was estimated to determine the mean period runoff. The records of flow in the forks have been extended and adjusted to reflect natural conditions by correlation with the mean period runoff of the Chowchilla River at Buchanan Dam site.

Estimates of natural runoff of Chowchilla River at Buchanan Dam site made for Bulletin No. 1 of the State Water Resources Board, entitled "Water Resources of California", were used for the period from 1907-08 through 1910-11. For the period from 1911-12 through 1929-30, the values used were those developed by the U. S. Army Corps of Engineers for its Buchanan Project studies. Subsequent to 1929-30 the measured flow values were used. Comparison of the 50-year mean flow, so developed, with the 51-year mean computed by the Corps of Engineers for the period from 1911-12 through 1961-62 shows a difference of about 7,300 acre-feet annually.

Streamflow records for Chowchilla River at Buchanan Dam site indicate that flow varies between wide limits during a given year. For example, in 1955 when the maximum discharge of record (30,000 cubic feet per second) occurred on December 23, there was no flow from July 15 through November 25. The annual natural runoff also fluctuates widely from year to year varying from an estimated 265,000 acre-feet in 1910-11 to only 3,000 acre-feet in 1930-31. Table 7 presents the estimated mean annual natural runoff at selected stations in the Chowchilla River Basin. The annual natural runoff and the accumulated departure from the mean annual runoff of Chowchilla River at Buchanan Dam site are graphically depicted in Plates 5A and 5B, respectively.

Construction of the Buchanan Project on the Chowchilla River will reduce the surface water outflow from the area of investigation. It is estimated on the basis of reservoir operation studies that this outflow averaged 15,000 acre-feet annually during the six-year base period.

TABLE 7

ESTIMATED MEAN ANNUAL NATURAL RUNOFF AND MONTHLY DISTRIBUTION OF FLOW OF STREAMS AT SELECTED STATIONS IN AND NEAR MADERA AREA FOR 50-YEAR PERIOD, 1907-08 THROUGH 1956-57

50-Year Average Monthly Runoff, in acre-feet; and Monthly Percent of Yearly Total

	SAN JOAQUIN RIVER BASIN													
	Granite Creek Near Cattle Mountain		Jackass Creek Near Jackass Meadow		Chiquito Creek Near Arnold Meadow		North Fork Willow Creek Near Soquel Meadow		North Fork Willow Creek Near Bass Lake		Fine Gold Creek Near Mountain View School		San Joaquin River at Friant	
Month	Runoff	%	Runoff	%	Runoff	%	Runoff	%	Runoff	&	Runoff	%	Runoff	%
Oct.	768	0.8	75	0.4	773	1.1	178	1.0	893	1.7	34	0.2	19,723	1.2
Nov.	1,073	1.1	182	1.0	1,351	2.0	278	1.6	1,699	3.3	256	1.6	28,248	1.7
Dec.	1,626	1.7	265	1.5	2,414	3.5	661	3.8	3,483	6.8	1,303	8.3	57,635	3.4
Jan.	1,850	2.0	373	2.1	2,797	4.1	968	5.6	4,417	8.6	3,307	21.0	73,711	4.3
Feb.	2,066	2.2	487	2.8	3,943	5.7	1,291	7.5	5,422	10.6	4,552	28.7	92,225	5.4
March	6,279	6.6	2,214	12.6	7,968	11.6	2,069	12.0	6,893	13.4	3,877	24.6	136,217	8.0
April	16,106	17.0	4,612	26.3	14,464	21.1	3,749	21.7	8,681	16.9	1,667	10.6	244,499	14.3
May	32,936	34.9	5,951	33.9	19,736	28.7	4,443	25.8	9,778	19.2	599	3.8	430,151	25.2
June	25,741	27.2	2,981	17.0	10,971	16.0	2,492	14.4	5,908	11.5	145	0.9	392,261	23.0
July	5,560	5.9	398	2.3	2,396	3.5	825	4.8	2,255	4.4	25	0.2	163,380	9.6
Aug.	450	0.5	19	0.1	1,332	1.9	231	1.3	1,138	2.2	7	0	45,890	2.7
Sept.	125	0.1	3	0	525	0.8	85	0.5	743	1.4	8	0.1	19,841	1.2
Total	94,580		17,560		68,670		17,270		51,310		15,780		1,703,781	

	MERCED RIVER BASIN		CHOWCHILLA RIVER BASIN								FRESNO RIVER BASIN					
	Merced River at Exchequer		East Fork Chowchilla Near Ahwahnee		West Fork Chowchilla Near Mariposa		Middle Fork Chowchilla Near Nip-innawassee		Chowchilla River at Buchanan Dam Site		Fresno River Near Knowles*		Fresno River Near Daulton*		Lewis Fork, Fresno River Near Oakhurst**	
Month	Runoff	%	Runoff	%	Runoff	%	Runoff	%	Runoff	%	Runoff	%	Runoff	%	Runoff	%
Oct.	7,070	0.7	52	0.2	27	0.2	14	0.2	148	0.2	448	0.8	332	0.5	505	3.1
Nov.	17,480	1.9	450	1.8	241	1.8	126	1.8	1,331	1.8	1,350	2.4	1,844	2.7	350	2.1
Dec.	40,210	4.3	2,437	9.7	1,169	8.6	603	8.4	6,359	8.6	3,802	6.8	6,977	10.2	1,281	7.8
Jan.	60,240	6.4	4,885	19.4	2,617	19.3	1,415	19.7	14,270	19.3	4,875	8.8	8,369	12.2	3,524	21.3
Feb.	78,940	8.4	6,555	25.9	3,682	27.1	1,968	27.3	20,186	27.3	9,797	17.6	9,119	13.3	2,775	16.8
March	98,600	10.5	5,994	23.8	3,252	24.0	1,692	23.4	17,672	23.9	11,034	19.8	14,406	21.0	3,121	18.9
April	149,070	15.8	3,170	12.6	1,694	12.5	896	12.5	9,168	12.4	10,140	18.2	12,496	18.3	1,695	10.3
May	244,730	26.0	1,219	4.8	643	4.7	343	4.8	3,475	4.7	7,937	14.2	8,608	12.6	1,259	7.6
June	181,390	19.2	368	1.5	196	1.4	107	1.5	1,035	1.4	4,453	8.0	4,531	6.6	803	4.9
July	50,300	5.3	66	0.3	36	0.3	19	0.3	222	0.3	1,419	2.5	1,424	2.1	307	1.9
Aug.	10,410	1.1	12	0	7	0.1	4	0.1	39	0.1	321	0.6	239	0.3	338	2.0
Sept.	4,170	0.4	12	0	6	0	3	0	35	0	188	0.3	118	0.2	546	3.3
Total	442,610		25,220		13,570		7,190		73,940		55,764		68,463		16,504	

* Values shown for Fresno River near Knowles and Daulton include imports and are the averages for the historical periods from October 1917 through September 1961 and from October 1941 through September 1961, respectively.

** Does not include imports.

Under long-term conditions of water supply with the Buchanan Project completed, it is estimated that such outflow will average about 9,100 acre-feet annually.

Fresno River Basin

Although records of streamflow on the Fresno River have been compiled continuously since November 1915, these historic data include ungaged quantities of "foreign" water. Water from the Merced and San Joaquin watersheds has been imported since 1888 and 1897, respectively. Under a water right claim of the Madera Irrigation District, up to 50 second-feet of water is diverted from Big Creek near Fish Camp to the Lewis Fork of the Fresno River. The so-called Soquel Diversion on North Fork Willow Creek, about 6.5 miles north of Bass Lake, likewise transfers up to 50 second-feet of water to the Fresno River Basin. This diversion also is made under a claimed water right of Madera Irrigation District and will be discussed in more detail subsequently in the report. Until recently (1958 on Big Creek and 1960 at Soquel), records of the amounts of diversion were either nonexistent or sporadic. This inadequacy of records together with the fact that these diversions antedate any streamflow records in this vicinity make it difficult, if not impossible, to construct accurate estimates of natural flow for the affected streams. Therefore, it was considered more practical to extend the historical record to the 50-year mean period than to estimate the natural runoff of the Fresno River near Daulton.

The historical and computed runoff of the Fresno River near Daulton thus developed was compared with values used by the U. S. Army Corps of Engineers for its Hidden Project. This comparison disclosed an apparent discrepancy of 11,000 acre-feet annually for the mean periods used. The 51-year mean period used by the Corps of Engineers, however, is from 1911-12 through 1961-62 and includes the relatively dry years of 1958-59, 1959-60, and 1960-61. Further, the relatively wet years of 1908-09 and 1910-11 included in the 50-year mean period are excluded from the Corps' study. Analysis of the period common to both studies -- 1911-12 through 1956-57 -- disclosed a difference between the two studies of only 200 acre-feet in the mean annual runoff. Greater differences occur during individual years; these, however, may be attributed to the use of different streams for correlation studies and are not believed to be significant in the overall analysis of the hydrology.

Runoff and streamflow in the Fresno River Basin, in common with that of most California streams, vary between wide limits from year to year and from season to season. Estimated mean annual historical runoff of Fresno River at Daulton is 86,100 acre-feet. Contrasted with this is an estimated runoff of 318,500 acre-feet in 1937-38 which is 467 percent of the mean and 9,100 acre-feet in water year 1930-31. Streamflow at this station during the period of record (1941 to date) has varied from a maximum of 17,500 second-feet on December 23, 1955, to no flow at times during most years.

Estimated annual runoff at selected stations in Fresno River Basin is shown in Table 7. Plates 6A and 6B show, respectively, the estimated historical runoff and accumulated departure from the mean annual runoff of the Fresno River near Daulton.

Reservoir operation studies conducted for the Hidden Project indicate that Fresno River water flowing out of the area of investigation averaged 19,800 acre-feet annually during the six-year base period. These studies also indicate that with construction of the Hidden Project the average long-term outflow from the Fresno River will be reduced to 9,700 acre-feet annually.

San Joaquin River Basin

Although the previously discussed stream systems are tributary to the San Joaquin River, this portion discusses that part of the watershed within the area of investigation which drains directly to the main stem or major forks of the San Joaquin River. Runoff records for this portion of the San Joaquin River Basin are more extensive than for the other three streams draining the area. A continuous record of runoff of the San Joaquin River below Friant has been maintained since 1907. Many other stations also are gaged regularly and have various lengths of record.

The San Joaquin River is regulated by nine reservoirs and provides flows for twelve powerplants. The largest of these reservoirs (Millerton Lake, at a streambed elevation of about 350 feet above sea level and located on the Madera-Fresno County line) has a usable capacity of about 390,000 acre-feet above the Friant-Kern Canal outlet. The remaining eight reservoirs have a total usable storage capacity of about 609,000 acre-feet. The earliest storage began at Bass Lake (formerly Crane Valley Reservoir) in 1901. Bass Lake is the only one of these reservoirs located entirely within the study area and is owned and operated by Pacific Gas and Electric Company for hydroelectric power generation. The original dam, built in 1901, was raised in 1910 to its present height, thereby increasing the usable capacity of Bass Lake to 45,100 acre-feet.

Mammoth Pool Dam and Reservoir, located on the main stem of the river, is owned and operated by Southern California Edison Company for generation of hydroelectric power. The boundary of the area of investigation passes through this reservoir, which was completed in 1960 and is the newest on the San Joaquin River. It has a usable capacity of 119,900 acre-feet above a minimum pool of 2,780 acre-feet. The remaining six reservoirs mentioned above are located on forks or tributaries of the river within Fresno County, outside the area of investigation.

Although the flow in the San Joaquin River is presently regulated to a large degree by the reservoirs previously mentioned, estimates of natural runoff were made at several stream gaging stations and at potential water development sites. Surface water records of the San Joaquin River at Friant indicate the following characteristics:

1. Mean annual runoff for the 50-year period is 1,703,800 acre-feet.

2. The maximum estimated annual natural runoff occurred in 1937-38 and was 3,688,400 acre-feet, or 216.5 percent of the mean.

3. Minimum annual natural runoff was 444,900 acre-feet, or 26 percent of the mean, and occurred in 1923-24.

4. The maximum recorded streamflow prior to regulation by Millerton Lake was 77,200 second-feet on December 11, 1937.

5. A minimum discharge of 30 second-feet was recorded on July 29, 1940.

Table 7 shows estimated mean annual natural runoff at selected locations in the San Joaquin River Basin. The estimated natural runoff and accumulated departure from the mean annual runoff of San Joaquin River below Friant are shown graphically on Plates 7A and 7B, respectively.

Other Streams

In addition to the four major streams discussed in the preceding paragraphs, there are several minor ungaged streams in the Madera area. The minor streams drain about 76 square miles of foothill watershed and contribute runoff to the valley floor. Inflow to the valley floor from this ungaged area was estimated by using the concurrent records of the runoff of Cottonwood Creek near Friant and of the precipitation stations at Friant Government Camp and San Joaquin Experimental Range in an area-precipitation correlation. Results of the study for the nineteen seasons of concurrent record (1941-42 through 1959-60) indicate a mean runoff of approximately 7,000 acre-feet annually from the ungaged minor streams at the foothill line. Maximum and minimum computed annual runoff was 37,000 acre-feet in 1957-58 and zero in 1958-59.

Runoff Summary

Runoff from the mountainous areas contributing to the water supply of the valley floor includes the following:

1. Estimated natural flow of the Chowchilla River at Buchanan Dam site.

2. Estimated historical flow of Fresno River at the gaging station near Daulton including imports to the basin from Big Creek and North Fork Willow Creek.

3. Estimated natural flow of ungaged minor streams above the foothill line.

Although the San Joaquin River contributes relatively large amounts of water to the area, these quantities are not discussed in this section but are discussed subsequently under the headings "San Joaquin River Surface Diversions" and "Subsurface Flow".

Estimates of average annual runoff from the mountain areas above the foothill line are summarized in Table 8 for the mean period (1907-08 through 1956-57) and the base period (April 1952 through March 1958).

TABLE 8

SUMMARY OF MEAN AND SIX-YEAR BASE PERIOD RUNOFF TO VALLEY FLOOR FROM MOUNTAIN AREAS IN MADERA AREA

(in Thousands of Acre-feet per Year)

	Base Period	Mean Period	Base Period in Percent of Mean Period
Fresno River near Daulton (including imports)	72.6	86.1	84.3
Chowchilla River at Buchanan Dam Site	57.2	73.9	77.4
Minor Streams	8.2	7.0	117.1
Total	138.0	167.0	

Ground Water--Valley Floor Portion

The San Joaquin Valley is a huge ground water basin containing permeable water-bearing sediments underlain and surrounded on three sides by consolidated impermeable rocks. Madera County is located in the east central portion of the San Joaquin Valley and is bounded on the east by crystalline bedrock of the Sierra Nevada, on the south and west by the San Joaquin River, and on the north by the Chowchilla River.

A reconnaissance study of the ground water geology was performed to determine, evaluate, and summarize the geologic factors which affect the occurrence, movement, recharge, and chemical quality of ground water in the area. The geologic investigation consisted of compiling and reviewing previous geologic reports and maps, obtaining and evaluating available logs of wells within the study area, and interpreting recorded ground water levels and chemical water quality analyses. A limited amount of field work was performed.

Two other comprehensive ground water investigations significant to this area are currently in progress. These are "Planned Utilization of the Ground Water Basins of the San Joaquin Valley" by the Department of Water Resources, and a ground water investigation in the Madera area by the U. S. Geological Survey in cooperation with the Department of Water Resources.

Because of the studies cited above, a detailed ground water study of the valley floor area was not undertaken during this investigation. Instead, all available information was utilized in preparing the following discussion.

Ground Water Geology

The San Joaquin Valley is an asymmetrical, elongated basin bounded on three sides by mountains. The structural and topographic troughs of the basin do not necessarily follow the same line. The mountains are the Sierra Nevada on the east, the Coast Ranges on the west, and the Tehachapi and San Emigdio Ranges on the south. The axial trough of the basin is located southwest of the center line of this northwest striking valley. The Valley is underlain by a thick section of gently folded marine sediments of Cretaceous and Tertiary age and unconsolidated Upper Tertiary and Quaternary alluvial materials, on top of crystalline basement rock of Paleozoic and Mesozoic age (section B-B', Plate 8). The Upper Tertiary and Quaternary alluvial materials were deposited as alluvial fans and flood plain deposits by the streams flowing from the surrounding mountains as they emerged from the foothills into the Valley, and as lake and swamp deposits in the low flat interior portions of the Valley. As the alluvial fans grew from continuous deposition, they began to merge with adjacent fans to form a continuous, gently sloping piedmont plain along the perimeter of the Valley. These Upper Tertiary and Quaternary continental deposits contain fresh water which is suitable for most beneficial uses and which comprises the effectual ground water body of the San Joaquin Valley. The older Cretaceous and Tertiary marine consolidated and semiconsolidated sediments contain ground waters high in salts; the underlying crystalline basement is essentially nonwater-bearing.

The valley floor portion of Madera County ranges in elevation from 120 feet above sea level along the valley trough to about 450 feet above sea level along the Sierra Nevada foothills. The lower areas of the Valley, to an altitude of 300 feet, are characterized by low alluvial plains and fans, river flood plains and channels, and overflow lands. To the east and above 300 feet in altitude, the topography becomes hilly and is referred to as "dissected uplands" underlain by older, compacted alluvial fan materials.

The San Joaquin River below Friant, as it emerges from the Sierran foothills into the San Joaquin Valley, has carved a mile-wide flood channel approximately 100 feet deep. The stream itself meanders within the confines of the bluffs carved by the downcutting stream. To the west, the flood channel varies in width from over a mile to less than a half mile as it crosses U. S. Highway 99, and the entrenchment of the channel decreases to less than 50 feet near Biola before reaching the level of the surrounding surface at Gravelly Ford Ranch. Then, along the interior valley floor area, the San Joaquin River meanders northwesterly within the confines of natural levees and within a zone that ranges in width from one to two miles. These natural levees were formed at times of flood when the river overflowed its flood plain and deposited large amounts of silty material in the form of low ridges. This process has raised the level of the San Joaquin River above portions of the surrounding area in the valley trough. The Fresno River has been deflected to the northwest by the eastern natural levee and parallels the San Joaquin River for many miles before it drains into the braided channel networks of the latter.

The lesser intermittent streams emerging from the Sierran foothills also have been entrenched into the hardpan covering the dissected upland, but the depth of entrenchment is much less than is that of the San Joaquin River. Subsequently, these entrenched channels have been backfilled by young alluvial deposits. The natural levees along these lesser stream courses in the central valley floor portion are hardly discernible.

Geologic Units and Their Water-bearing Properties

The distribution and relationships of the various geologic formations are shown on Plate 9, "Regional Geology". For the purposes of this summary, only the water-bearing formations are discussed in detail, whereas the less significant nonwater-bearing formations are only briefly discussed as a group. Some of the formations discussed do not crop out in the Madera area and consequently are not shown on the regional geologic map. These formations do occur beneath the surface of the valley floor, however, and significantly affect ground water conditions on the valley floor.

Basement Complex. The basement complex, which is nonwater-bearing, consists of metamorphic rocks and intrusive igneous granitic rocks of Paleozoic and Mesozoic age which constitute the bulk of the Sierra Nevada. These units essentially form the eastern boundary of the ground water basin and dip gently under the valley fill sediments. The basement complex was encountered in deep petroleum exploration holes at a depth of about 4,000 feet along U. S. Highway 99 and at a depth of about 9,000 feet just east of the valley trough in the Madera area.

Cretaceous and Tertiary Marine Sediments. The Cretaceous and Tertiary marine sediments which overlie the basement complex consist of folded and faulted beds aggregating in excess of 8,000 feet in thickness in the Madera area. These sediments, predominantly sandstone, shale, and conglomerate, do not crop out in the Madera area. Included in this grouping are the Panoche and Moreno Formations of Upper Cretaceous age and Domegine, Kreyenhagen, Zilch, and Santa Margarita Formations of Tertiary age. In most places these formations contain saline or dilute saline waters indigenous to the formation (connate water). Only locally along the eastern edge of the Valley do they contain fresh waters where the saline waters have been flushed and replaced by fresh water infiltrating from surface sources. It is suspected that waters from these sediments have not been tapped by water wells in the Madera area.

Tertiary Continental Sediments. The Tertiary continental sediments include sand and weathered clay of the Ione Formation, rhyolite detritus of the Valley Springs Formation, and volcanic sand of the Mehrten Formation. These formations occur along the eastern margin of the Valley and gently dip westward under the younger valley fill sediments. Near the surface they have been truncated and are overlain by flatter-lying younger sediments of the Friant Formation and old alluvial fan deposits. Of the Tertiary continental sediments, only the Ione Formation crops out in the Madera area.

The outcrops occur as local, small erosional remnants of sandstone capping the basement complex along the eastern edge of the Valley.

These Tertiary continental sediments contain water of fairly good quality but are not ordinarily tapped by water wells. Beneath most of the Valley, these formations are too deep to be developed economically by wells.

Friant Formation. The Friant Formation of Upper Tertiary age consists of loose to compacted fluviatile fan sediments, predominantly sand with interbeds of silt and a few local gravel lenses. These sediments are usually well sorted. The upper beds are usually buff colored and locally characterized by rhyolitic pumiceous sand and fine gravel content, while the lower beds are greenish-gray. The Friant Formation dips gently westward and crops out as a broad belt along the eastern valley floor margin from the Chowchilla River to the San Joaquin River and then discontinuously southeasterly to the Kings River. Local, thick, highly permeable gravel accumulations occur in the upper part of the formation, both north and south of the San Joaquin River. These represent relic channels of the San Joaquin River. For the most part, however, the Friant Formation ranges in permeability from low to moderate.

Tulare Formation. The Tulare Formation which crops out along the west side of the San Joaquin Valley may be equivalent in age to the Friant Formation and old alluvial fan deposits. It has been gently folded and dips under the more recent valley fill and forms a broad syncline under the San Joaquin Valley. Beneath the more recent valley fill the Tulare Formation is believed to merge to the east with the westerly dipping Friant Formation and old alluvial fan deposits. The Tulare Formation is essentially an alluvial fan deposit consisting of argillaceous sand and silt containing lenses of poorly sorted coarse sand and gravel. These are generally loose to semiconsolidated; in drill holes, the distinction between the Tulare Formation and the overlying alluvial fan deposits can hardly be distinguished. Within the Tulare Formation are numerous discontinuous clay lenses, including a significant, apparently continuous clay bed which covers most of the western central and northern San Joaquin Valley. This continuous clay bed, deposited in a fresh water lake environment, is diatomaceous and is commonly referred to as the Corcoran Clay. From the western portion of the San Joaquin Valley it extends easterly to approximately three miles west of U. S. Highway 99 in Madera County.

The Tulare Formation contains water of suitable quality for irrigation except locally in the basal portion where saline waters occur. Along the west side of the San Joaquin Valley, this formation is extensively tapped by wells.

Old Alluvial Fan Deposits. The old alluvial fan deposits of Pleistocene age represent old alluvial fan-head, mid-fan, and terrace deposits along the eastern edge of the Valley. These deposits consist of unconsolidated to loosely consolidated, poorly sorted gravel, sand, and silty clay. Well-developed soils and clay pans are characteristic of these deposits. The subsoils locally may contain salts. Portions of the old alluvial fan surface have been dissected by down-cutting intermittent streams, and the resulting carved channels have been backfilled by Recent alluvial fan deposits.

Generally, the old alluvial fan deposits are poorly to moderately permeable. Moderately deep wells are tapping this formation east of U. S. Highway 99. According to drillers' well logs, drilled wells have encountered numerous clay beds, some of which are up to 80 feet thick. Yields of wells have been highly variable.

Basin Deposits. The Recent basin deposits are accumulations of unconsolidated fine silty and clayey sand, silt, and clay occurring in the low, flat valley trough and outer fan areas. These contain alkali soil and saline water at shallow depths near the valley trough. The permeability of these fine-grained deposits is generally low to moderate. The poorly permeable surface materials of this formation allow only minor downward movement of water. The basin deposits supply water to shallow wells in western Madera County.

Young Alluvial Fan and Basin Rim Deposits. The young alluvial fan and basin rim deposits, of Recent age, are the alluvial fans of present streams and distributaries and the flood plains of the San Joaquin River along the valley trough, respectively. The alluvial fan deposits consist of unconsolidated, undeformed sand and silt with lenses of gravel and clay. As these fans became larger and more extensive, they began to coalesce with adjacent fans and formed an alluvial apron or a piedmont plain. The basin rim deposits consist of fine sand, silt, and clay and are the deposits located in the flood channel of the San Joaquin River in the valley trough area.

The young alluvial fan and basin rim deposits are moderately to highly permeable and they contain the most significantly developed aquifer in the valley floor portion of Madera County. The thicknesses of these deposits could not be established because samples from drill holes are similar to the underlying Tulare Formation, Friant Formation, and old alluvial fan deposits.

Wells in Madera County are generally shallow (less than 300 feet) and located within the areas of the more suitable, free-draining soils of the alluvial fans. Most of these wells tap ground water from the alluvial fan deposits. Currently, wells in the lower portions of the Valley are being drilled to greater depths with the result that water is perhaps being withdrawn from the Tulare Formation, both above and below the Corcoran Clay.

Occurrence and Movement of Ground Water

Ground Water Occurrence. Fresh ground water in the valley floor portion of Madera County occurs principally in the upper portions of the unconsolidated continental deposits, the maximum thickness of which is about 3,000 feet. Below depths of from 700 to 1,000 feet in the valley trough, however, the water has been found to be generally unsuitable for long-term irrigation use.

Beneath the western portion of the Madera County valley floor, fresh ground water occurs in downward succession in an unconfined and semiconfined water body in alluvial deposits of Recent, Pleistocene, and late Pliocene age overlying the Corcoran Clay and in a confined water body beneath the Corcoran Clay bed in alluvial and lake deposits of late Pliocene age. In the eastern portion of the valley floor, beyond the eastern extent of the Corcoran Clay, the ground water body is essentially unconfined and semiconfined, though it may be confined locally. Recent water level measurements and water quality data collected by the U. S. Geological Survey and the Department of Water Resources indicate the presence of a perched ground water zone in the western, or valley trough, area of the valley floor. This condition has arisen from the general lowering of the shallow unconfined and semiconfined zone in the valley trough area, leaving a ground water body perched upon drainage-restricting clay beds at depths of about 40 feet. This perched ground water body is of poor quality. The areal extent of the perched water body could not be fully delineated.

With the exception of the perched water zone the fresh water body as a whole is essentially a continuous water body within the Madera valley floor area and in adjacent areas within the ground water basin. Any change either in total pumping draft or in the amount of surface recharge in one area affects ground water conditions in adjacent areas. Sometimes such changes affect even remote areas but the greater the distance the less effect such changes have.

Ground Water Recharge. The original source of ground water is precipitation upon the tributary drainage basins and upon the valley floor. Recharge to the unconfined and semiconfined ground water body is provided by seepage from streams, underflow in permeable materials flooring the canyons bordering the Valley, seepage losses from irrigation canals and ditches, deep penetration of water applied for irrigation in excess of plant requirements, and deep penetration of rainfall on the valley floor. Much of this recharge occurs in the more permeable upper and middle fan areas of the young alluvial fan deposits. Seepage from natural runoff, losses from irrigation canals and ditches, and return flow of excess irrigation water are the major means of recharge throughout most of the Madera area. The principal source of recharge in the southern portion of the area is the perennial San Joaquin River. Lesser streams, particularly the Fresno River and the Chowchilla River together with the latter's distributaries, Ash and Berenda Sloughs, contribute greatly to the ground water because of the augmentation of the natural flows by Madera Canal releases into these streams. These stream channels together with Dry and Cottonwood Creeks have moderate seepage rates and are used for artificial recharge whenever water is available in excess of demand.

Because the amount of rainfall is low, the amount of direct recharge from rainfall is still considered to be small even in the more permeable areas west of the hardpan soil belt area of the Friant Formation and old alluvial fan deposits along the eastern portion of the area. Rainfall, however, meets the early seasonal demands for water which would otherwise have to be pumped. Therefore, rainfall can be thought of as a significant source of water supply even though the direct recharge to the ground water itself may be small.

Recharge to the confined ground water beneath the Corcoran Clay is from the unconfined and semiconfined ground water body beyond the eastern edge of the confining bed, and also in part by leakage through wells and by slow downward penetration through the confining bed where the hydraulic head of the confined water body is lower than that of the unconfined water body.

Ground Water Movement. Before ground water was developed in the Valley, the ground water levels were at or near the ground surface over much of the valley area, and the movement of ground water in Madera County was downslope from the Sierran foothills southwesterly to the valley trough area and into the San Joaquin River. Accumulated waters in the swampy valley trough area in part ran off and in part evaporated, leading to the accumulation of salts in the basin deposit soils.

Development of the unconfined and semiconfined ground water by pumping has lowered the ground water levels and locally caused ground water gradients toward pumping troughs. The swampy areas in the valley trough have receded, and portions have been reclaimed for agriculture. Also, the lowering of the water levels has induced influent seepage from the San Joaquin River into the ground water body in the southern portion of the valley floor; prior to ground water development, ground water seeped into the river. A ground water map for fall of 1939 indicated a movement of ground water from Fresno County obliquely (northwestward) under the San Joaquin River toward pumping troughs in Madera County. Since then the draft on ground water in Fresno County has increased and modified the gradient to such an extent that a ground water ridge under the San Joaquin River now separates two pumping troughs on opposite sides of the county line.

In the central and northern portion of the valley floor the current general trend of the ground water is still downslope westward toward the valley trough and then northwesterly to a pumping depression centered near El Nido, Merced County. This general gradient is interrupted by numerous pumping depressions interspersed with ridges and mounds.

The gradient in the unconfined and semiconfined ground water along the eastern portion of the valley floor in the poorly to moderately permeable Friant Formation and old alluvial fan deposits slopes southwesterly approximately 10 feet per mile. The gradient in the southwestern portion regularly flattens out to two or three feet per mile despite heavy pumping, indicating the presence of relatively permeable aquifers. The ground water levels are highly irregular in the northwestern portion with steeply sloping ground water ridges underlying streambeds and irrigation laterals, and with depressions in pumping areas. These irregularities of the ground water surface indicate that the underlying alluvial beds are not as permeable as those beds in the southern portion of the area.

In 1958 the shallow ground water level in the flat valley trough areas was a nearly static level surface interrupted only in local areas where shallow wells were pumping. Water levels in this area were from 10 to 20 feet below the land surface. Since then, this shallow ground water level has gradually declined with a resulting body of water perched upon restrictive clay beds above the unconfined water table.

Water level measurements during February of 1965 indicate the unconfined water level in the trough area was about 50 feet below the land surface and the level of the perched water table ranged from 10 to 40 feet below the land surface. Little is known about the monthly and yearly fluctuations of levels of the ground water bodies in this area.

Movement of the confined ground water in the Madera area is from its forebay area east of the edge of the confining bed, southwesterly to the heavy pumping areas in the Los Banos-Mendota area along the west side of the San Joaquin Valley. Newly constructed wells in excess of 300 feet deep located just east of the valley trough area within Madera County have only recently begun pumping from the confined water body to a significant degree.

State Well Number. The well numbering system used in this report was developed by the U. S. Geological Survey and is based on the township, range, and section subdivision of the Public Land Survey. It conforms to the system used in all ground water investigations made by the Geological Survey in California and has been adopted by the Department of Water Resources. In this report the number which is assigned to a well in accordance with this system is referred to as the "State Well Number".

Under the system each section is divided into 40-acre tracts lettered as follows:

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

Wells are numbered within each 40-acre tract according to the chronological sequence in which they have been assigned State Well Numbers. For example, a well which has the number 16S/15E-17K1 would be in Township 16 South, Range 15 East, Section 17, and would be further located as the first well assigned a State Well Number in Tract K. In this report, well numbers are referenced to the Mount Diablo Base and Meridian.

Water Level Fluctuations. Under natural conditions, water levels fluctuate cyclically corresponding to available water supply for recharge and natural discharge from the ground water body. On a seasonal basis the levels range from a spring high to a fall low, with a subsequent spring recovery. Long-term trends of water level fluctuations respond to long-term wet and dry cycles. These seasonal and long-term fluctuations are greatly accentuated or modified by seasonal irrigation over a number of years. The seasonal and long-term fluctuations (hydrographs) of a few selected wells are illustrated on Plate 10. The locations of these wells are shown on Plate 11. These hydrographs indicate a maximum seasonal range of fluctuation of 20 feet. The long-term trend indicates the general ground water levels are declining. The water level in well 10S/17E-9A1, located near Sharon, declined at a rate of 3.8 feet per year between 1950 and 1963. A rate of about 3.2 feet decline per year between 1950 and 1960 was noted in well 12S/16E-27R, located 12 miles southwest of Madera.

When water deliveries from the Madera Canal to the Chowchilla Water District -- then a part of the Madera Irrigation District -- commenced in 1945, the effect of the added water was evident in wells within the service area. Water levels in the areas of direct recharge held steady from 1945 to 1948 and then began to rise slowly, although runoff from local streams was subnormal for the period. From south of Chowchilla to the San Joaquin River, well hydrographs still indicated a steady downward trend even with the additional recharge from the Madera Canal deliveries. The U. S. Bureau of Reclamation in July 1961 outlined the probable cause of the continually declining water levels contemporaneous with the augmentation of natural supplies by Madera Canal deliveries as follows:

(a) Increased irrigation demand.

(b) Greatly increased draft on the west side of the San Joaquin Valley from the confined water body resulting in depletion of ground water storage in the forebay area.

(c) Limited subsurface permeabilities controlling the quantity of recharge from surface sources.

Because the confined water body in the Madera area has not been extensively tapped by wells, the trend of the piezometric head has not been closely monitored. The hydrograph of a well (U. S. Bureau of Reclamation, No. 10S/14E-8B4) located near Red Top and perforated beneath the Corcoran Clay shows a gradual decline, reflecting increasing subsurface outflow in response to pumping from the deep zone on the west side of the San Joaquin Valley. During 1905-07 the piezometric surface in the same area stood above the ground surface and caused artesian flows from wells. In the spring of 1957, U. S. Bureau of Reclamation Well No. 10S/14E-8B4 indicated the piezometric surface to be 40 feet below the land surface, indicating a decline of at least 40 feet. This level was 10 to 20 feet above the free to semiconfined water body which was being pumped to a much greater degree than the confined body within the area. Since then the continued heavy pumping draft on the west side of the San Joaquin Valley and the recent construction of deep wells along the valley trough area in Madera County have lowered the piezometric head of the confined aquifer to well below the levels of the unconfined and semiconfined water surface. By 1964 the piezometric surface had dropped to about 150 feet below the land surface in places along the valley trough. The drop was much more marked in the heavily pumped areas west of Madera County. This lowering of the piezometric surface within the confined deposits has resulted in compaction of the water-bearing materials accompanied by subsidence of the land surface (deep subsidence). Recently, deep subsidence has been noted in the valley trough area in Madera County. It is believed that this subsidence has been due to the recent acceleration of pumping from the confined aquifer in western Madera County and/or the continued heavy pumping in areas to the west.

Ground Water Storage

From data collected for the San Joaquin River Basin Investigation in 1961 by the Department of Water Resources, estimates were made of the ground water storage capacity beneath the valley floor portion of Madera County. It was estimated that 3 million acre-feet could be stored in the pore space above the water table at that time.

The ground water storage capacity was estimated by applying the specific yield of each depth interval to the gross area of each unit area as follows:

$$s_1 = A_1 \left(d_1\, sy_1 + d_2\, sy_2 \ldots\ldots + d_n\, sy_n\right)$$

and

$$S = s_1 + s_2 + s_3 \ldots\ldots + s_n$$

Where:

s is the storage capacity of a subarea in acre-feet

A is the area of the subarea in acres

d is the depth of interval considered in feet

sy is the average specific yield for the interval expressed as a fraction or percentage

S is the storage capacity for the total area considered in acre-feet

The specific yield of a sediment is defined as the ratio of the volume of water which a saturated sediment will yield by gravity drainage to the total volume of the saturated sediment, customarily expressed in percent. The following specific yields were assumed for the various typical materials:

Gravel	= 25%
Sand; medium to coarse grained	= 25%
Sand; fine grained	= 10%
Silt	= 5%
Clay	= 3%

Preliminary results of a study in progress by the U. S. Geological Survey in cooperation with the Department of Water Resources indicate that these values are probably low. Therefore, storage changes calculated with these values are probably conservative.

Agricultural development using surface and well waters occurred in the valley floor area of Madera area as early as the late 1800's. W. C. Mendenhall* reported that there were 30 flowing wells aggregating a total flow of 8 cubic feet per second in the 350 square miles of artesian water-bearing land in the western one-third of the Madera valley floor area. These wells were 200 to 400 feet deep. Mendenhall also reported the existence of 15 pumping plants in the county for irrigation in 1906, mostly in the vicinity of Borden where ground water levels were at a depth of 10 to 20 feet. Pumping lifts were usually 25 to 40 feet.

Subsequently, the draft on the basin has increased rapidly, spurred by intensive irrigation development during the late 1940's. Both free ground water levels and the piezometric head have gradually declined. All the flowing wells reported by Mendenhall have long since ceased to flow.

*See Bibliography.

The following data on wells and well performances for the Madera area are from U.S.G.S. Water Supply Paper No. 1618*.

Average depth of wells (1949-1954): 250 feet.

Estimated agricultural pumping (1955-1956): 800,000 acre-feet.

Range of average well yield and drawdown (1955-56)

East of U.S. Highway 99: From a yield of 439 gpm (gallons per minute) and a drawdown of 16 feet to a yield of 939 gpm and a drawdown of 20 feet.

Southwest Valley Floor portion: From a yield of 546 gpm and a drawdown of 17 feet to a yield of 1,813 gpm and a drawdown of 18 feet.

Northwest Valley Floor portion: From a yield of 509 gpm and a drawdown of 18 feet to a yield of 987 gpm and a drawdown of 16 feet.

As water levels decline, wells are being constructed to a greater depth. The pumping of greater drafts from the lower confined ground water body in the western portion of the Madera valley floor area further lowers the piezometric surface and causes subsidence of the land surface.

A program of artificial recharge was undertaken by the Madera Irrigation District and the Chowchilla Water District following construction of Friant Dam which made it possible to conserve much of the San Joaquin River runoff that would otherwise waste to the sea. Nonfirm water supplies are purchased at low cost by the Districts. This water is delivered to the irrigators or spread for ground water replenishment, depending upon the demand for water at the time it becomes available. As previously mentioned, spreading areas include stream channels such as the Chowchilla River, Ash Slough, Berenda Slough, Dry Creek, the Fresno River, and Cottonwood Creek; irrigation canals; and laterals. This program of artificial recharge has enabled water levels to hold steady or to make slight, local recoveries in the Chowchilla area and has reduced the magnitude of the general decline in the area from south of Chowchilla to the San Joaquin River.

The physical aspects of an extensive program of artificial recharge of the ground water basin operated in conjunction with surface storage have been studied by the U.S. Geological Survey (Davis, et al., 1964*). An important

*See Bibliography.

factor in all programs of artificial recharge is the availability of suitable quality water. Recharge by spreading or ponding water on the surface may be limited by relatively impermeable surface soil or subsoils and impermeable subsurface deposits which restrict the movement of water to deeper, more permeable deposits. There are favorable areas for surface recharge spreading sites south and southwest of Madera, as indicated by the U. S. Geological Survey. Depth to the water table was 60 to 80 feet in 1964. There is a possibility that raising the water table at these potential recharge sites would cause a recurrence of a high ground water table problem to the west along the valley trough area.

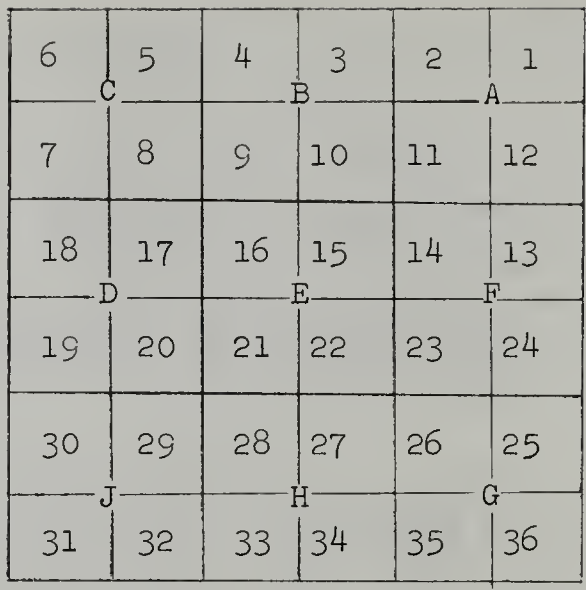
The areas east of U. S. Highway 99 are generally not suitable for artificial recharge because of the presence of an extensive hardpan covering, except in the southern portion along the San Joaquin River. It is suspected that a significant portion of water applied for artificial recharge in this excepted southern portion would seep southwestward to the San Joaquin River in the bluff area east of U. S. Highway 99.

Effective artificial recharge in other areas in the Madera valley floor area is somewhat limited by restrictive surface and subsurface deposits. However, a spreading of water along stream channels by the Chowchilla Water District and the Madera Irrigation District has had varying success.

The effects of the operation of the San Luis Project, whereby imported surface water will serve areas along the west side of the San Joaquin Valley where heavy draft upon the confined water body is occurring, cannot yet be fully evaluated. The project operation will enable farmers on the west side to reduce the heavy pumping draft on the lower confined aquifer and thereby should reduce the subsurface outflow from the Madera area and other areas east of the confining bed.

The proposed flood control projects of Buchanan Dam on the Chowchilla River and Hidden Dam on the Fresno River, when completed, will conserve for beneficial uses flood waters which would otherwise waste to the sea. These projects will also increase the water supply available to the Madera area.

<u>Change in Ground Water Storage</u>. The average annual change in ground water storage during the six-year base period for the valley floor portion of Madera County was computed in the following manner. Each township was subdivided into nine subareas of four sections each as shown below:



The average ground water elevation for each subarea at both the beginning and the end of the base period was determined from ground water contour maps. Lines of equal elevation of water in wells for the spring of 1952 and spring of 1958 are shown on Plates 12 and 13, respectively. Plate 14 shows lines of equal change in depths to water on the valley floor during the six-year base period. For each township, the appropriate specific yield corresponding to the average depth to water was selected from an earlier study. The area of each one-ninth township subarea was estimated in square miles (to the nearest tenth of a square mile where a boundary of the area of investigation crossed a subarea).

The average annual change in ground water storage for each subarea was then computed from the equation:

$$S = Sy \left(\frac{El_2 - El_1}{6} \right) 640\ A,$$

Where:

S is the average annual change in storage over the six-year base period in acre-feet;

Sy is the specific yield as a decimal number;

El_2 and El_1 are the average elevations of water at the end and at the beginning, respectively, of the six-year base period;

6 is the number of years in the base period;

640 is a constant to convert square miles to acres; and

A is the number of square miles in the subarea.

A negative change in storage indicates a lowering of the water table and vice versa.

Following the computation of change in storage for each subarea, the values were added algebraically to determine the overall change in ground water storage. For the valley floor portion of Madera County, this averaged -52,800 acre-feet annually during the period from April 1952 through March 1958. This averages a little less than one-tenth acre-foot per acre per year for the 547,000-acre valley floor portion of Madera County.

The estimates of the change in ground water elevations and of specific yields in the above computations are each considered to be subject to about 25 percent error because of a lack of sufficient data. It is believed that the actual average annual change in ground water storage, therefore, could range between -30,000 acre-feet and -83,000 acre-feet.

Ground Water -- Oakhurst-Ahwahnee Area

Because of the potential increase in homesite development in the mountainous-foothill area of Oakhurst-Ahwahnee, formerly known as Fresno Flats, a ground water study of a reconnaissance scope was undertaken. Compared with the pervious sedimentary and alluvial materials which contain and transmit water through their interstices, the crystalline bedrock which underlies the Oakhurst-Ahwahnee area could be considered essentially as nonwater-bearing. The ground water supply that does occur within the bedrock unit is confined to fracture openings in the otherwise impermeable bedrock. However meager this ground water supply is, it currently represents virtually the only developed source of domestic water supply and may possibly become very significant as an additional supply for future development. For this reason, the Oakhurst-Ahwahnee drainage area is treated here as a ground water area with zones of fractured granitic rocks representing aquifers. The number of wells constructed within the area could not be estimated but there may be several hundred. With the land actively being subdivided by developers, the number of wells constructed in recent years has been increasing and probably will continue to increase as the land is subdivided. For the purpose of this study, the boundary of the Oakhurst-Ahwahnee area or basin is the drainage divide as outlined on Plate 9.

Located in the Central Sierra Nevada foothills in Madera County, the Oakhurst-Ahwahnee basin includes the area drained by the Fresno River and its tributaries above Windy Gap. Windy Gap, a narrow, rocky water gap, forms the basin outlet through a ridge formed by Crook and Potter Mountains. The principal tributaries of the Fresno River in the basin include Lewis Fork, Nelder Creek, Miami Creek, and Peterson Creek. The topography is mountainous and is moderately steep in the higher basin rim areas and becomes somewhat flatter in the lower areas. The basin ranges in altitude from 1875 feet above sea level at Windy Gap to 7131 feet at Speckerman Mountain on the drainage divide at the head of Lewis Fork. Local topography is principally controlled by the numerous joint systems which have developed on the bedrock surface. Runoff is actively carving the landscape, favoring joint plane weaknesses.

The purpose of this study was to determine and evaluate the geologic factors which affect the occurrence, movement, recharge, and chemical quality of ground water in the area. Also, a very generalized attempt was made to estimate the future potential development of ground water within the basin.

Only a limited amount of field work was undertaken for this reconnaissance study. Much of this study was based on elementary principles of ground water geology in crystalline rocks as outlined by C. F. Tolman* (1937) and on empirical data from a ground water hydrology study by P. M. Johnston* (1962) in the Fairfax Quadrangle, Virginia. Local well drillers and water pump distributors were interviewed in regard to well performances and current well construction practices. A total of 75 available logs of wells in the basin were inspected and evaluated as part of this study. Because of the somewhat generalized nature of this study, the basin principles assumed and the methods of approach used may be extrapolated and applied to nearby similar crystalline rock areas which are growing rapidly, such as the Bass Lake-North Fork, Raymond, and Coarsegold areas.

General Geology

The Oakhurst-Ahwahnee basin is underlain principally by Cretaceous-Jurassic age granitic rock. Smaller portions are underlain by pre-Cretaceous age metamorphic rocks and Recent stream channel alluvium as shown on Plate 9. Within the basin, much of the granitic bedrock is mantled by a thin, discontinuous soil and "decomposed granite" cover which was weathered in place. On the flatter valley portion of the basin where drainage is not as rapid as in the steeper basin rim areas, the "decomposed granite" mantle becomes more extensive and thicker. The depth of this mantle varies from 0 to

*See Bibliography.

over 100 feet. It is on this flatter topographic area that most of the home development has occurred and is expected to occur to a higher degree.

Most of the water from wells in the basin is obtained from fractures in the bedrock, but some is also obtained from the weathered residual soil and "decomposed granite" overlying the granitic bedrock.

Pre-Cretaceous Metamorphic Rocks

The pre-Cretaceous metamorphic rocks, which consist principally of schist, phyllite, and metavolcanic rocks, occur as erosional remnant roof pendants atop the ridgeline along the western drainage divide formed by Miami, Crook, Potter, Thornberry, and Goat Mountains. The schistosity or foliation, a dominant feature exhibiting parallel parting planes in metamorphic rocks, generally strikes northwest. The metamorphic rocks generally weather to a reddish-brown or yellow-brown clayey-silty soil containing mica flakes, quartz grains, and rock fragment grains. The average depth of weathering was not ascertained but it is suspected to range from 0 to 50 feet normal to the surface.

Due to the distribution of this formation along the ridgeline and its limited areal extent, the pre-Cretaceous metamorphic rock does not represent a significant source of water in the Oakhurst-Ahwahnee area.

Granitic Rock

The granitic rock unit, within which nearly all ground water development in the basin occurs, represents a portion of the Sierra Nevada batholith which consists of a series of acidic igneous intrusive bodies. During the upper Jurassic or lower Cretaceous periods these bodies intruded the pre-Cretaceous metamorphic rocks which once covered the area and have since been mostly stripped away by erosion. The granitic rock ranges in composition from granite to diorite. When unweathered, the granitic rock is light colored, medium grained, hard, and massive.

At the surface and in the zone beneath the surface, the unweathered granitics are dissected by numerous joint systems (parallel series of joints). Among the most persistent joint systems is one which is nearly horizontal or generally nearly parallel to the land surface. This system is probably caused by an upward extension of the rock mass resulting from the unloading of the overlying rock which once covered the area and has since been removed by erosion. Two other joint systems plus local random systems are generally prevalent for a given area. The frequency of jointing is expected to diminish with depth.

Exfoliation is commonly exhibited on surface outcrops. This accounts for the rounded and smooth nature of many of the granitic rock outcrops.

Ground water occurs in the joint and exfoliation fractures when these planes are open. Products of weathering in the form of clay have a tendency to form along joint and fracture planes and thereby impede or seal off the movement of ground water. Because fracture frequency diminishes with depth, the quantity of ground water diminishes with depth.

In the more topographically subdued areas of the granitic terrane, an extensive mantle of soil and "decomposed granite" of highly variable depth commonly develops. The soil cover in the area, which varies from a few inches to about three feet in thickness, is generally a reddish-brown clayey sand. It has a lower permeability and does not transmit water readily. This soil mantle is underlain by a highly variable depth zone of "decomposed granite" ranging up to 100 feet or more in thickness above the unweathered bedrock. This "decomposed granite" mantle resulted from deep in-place weathering of the granitic rock. This weathered rock has retained much of the original texture and color of the granitic rock but is generally soft and friable. The decomposed zone is intersected by numerous fractures and joints, many of which have been sealed by clays and other products of weathering. Residual boulders of relatively unweathered granitic rock are common within the decomposed mantle, some of which may be over 10 feet in diameter.

Ground water in the "decomposed granite" zone occurs chiefly in the residual open joints and fractures. In general, the "decomposed granite" itself is only very slightly permeable.

Alluvium

Alluvium, consisting of sand, silty sand, and some gravels, represents minor deposits along the stream courses. The depth of these deposits generally does not exceed 15 feet. These deposits are highly to moderately permeable and receive continuous recharge from streamflows and springs flowing from granitic rock which underlie them. As long as this recharge is sustained, shallow wells or infiltration gallery-type water systems could probably be developed in the alluvium. One system of the latter type is in operation along the Fresno River near Oakhurst. The current development of ground water from the alluvium in the basin is not generally extensive, however, because of the limited occurrences of alluvium along the stream channels. Shallow wells tapping this source could be subject to pollution from surface sources. Owing to its small area, the alluvium distribution in the Oakhurst area is not delineated on Plate 9.

Occurrence and Movement of Ground Water

Crystalline rocks themselves, because of their compactness and tightly interlocking grains, yield very little or no interstitial water to wells. Within this crystalline granitic rock basin, ground water occurs chiefly in open joints, fractures, and exfoliation planes, with perhaps smaller amounts in the interstitial openings in the "decomposed granite". Most of the rocks in the area have been considerably disturbed by earth movements and thus contain water-bearing openings. The depth below the surface to which joints and fractures may be open is limited by the ability of the rock to hold the fractures open under the weight of the overlying rock and soil mass.

Ground water movement in rock openings is influenced by physical character and the degree of interconnection of the joints and fractures. These tabular joint and fracture-filling water bodies vary in thickness and may be a mere filament of water. More often these tabular water bodies are of supercapillary size and subject to flow. The fissures either may be interconnected over a widespread area or may be a single fracture or group of fractures not connected with an adjacent water body.

If the openings are interconnected, a common water table results; if openings are isolated, each has an individual water table. The water-table slope in this mountainous area generally varies with the relief of the land surface and, hence, has greater relief than in the flatter plains underlain by pervious alluvial materials. Locally, however, the water table in fractured rock may be flatter if the interconnected fractures are of supercapillary size and frictional resistance is less than in interconnected capillary openings of tighter fractures or alluvial materials. Where the fractures are interconnected, the ground water would flow down the gradient along the fracture plane opening. Topography exercises a strong influence on the water-table slope since it controls the escape of effluent seepage. Streams in the Oakhurst-Ahwahnee basins are fed by effluent ground water seepage. This seepage is largely responsible for sustaining the streamflows long after seasonal precipitation and direct runoff have ceased.

Ground water in interconnected openings can occur under water-table (unconfined) conditions or pressure (confined) conditions. The confining pressure is caused by water moving down along an inclined open joint, or fracture, with the upper rock block acting as a confining layer.

Varying degrees of confinement could also be caused by a zone of relatively impervious soil or decomposed rock overlying a highly fractured, pervious bedrock. Individual confined conditions are limited to small areas, but so far as larger areas are concerned (or looking at the area as a whole), the water body may be considered as essentially that of a water-table condition.

Ground water in the Oakhurst-Ahwahnee area is derived from precipitation within the basin. In this mountainous area much of the rain falling and of snow melting upon the ground surface may run off directly, with the remaining portions seeping into the ground, being transpired by plants, or evaporating. The proportion of precipitation that follows each course depends upon duration and rate of precipitation, topography, soil and subsoil properties, kind and amount of vegetation, and season of the year.

Where bedrock is exposed, generally in areas of steeper slopes and limited vegetative cover, direct runoff is usually rapid and recharge is a much smaller portion of the total than in areas of lower relief and soil cover. Recharge seeps directly into fractures and, acting under the force of gravity, moves along open fractures to the ground water table.

Where the bedrock is completely fractured and disintegrated and where the bedrock is overlain by soil and decomposed rock mantle, direct runoff of precipitation is considerably less than it is where solid bedrock occurs at the surface, although it still amounts to a significant portion of the total precipitation. Not only is the surface topography much more subdued but also the residual soil and disintegrated rock serve as a sponge and temporary reservoir which absorbs rainfall and delivers it to the underlying fracture system. Of the precipitation that infiltrates the soil, a part may be absorbed by the soil moisture "reservoir" and a part may be returned to the atmosphere through plant transpiration and direct evaporation. The remainder moves down as recharge to the ground water.

In the Oakhurst-Ahwahnee area where infiltration data are lacking, an average figure of five percent of the total precipitation is assumed as potential recharge to ground water.

Ground Water Levels and Fluctuations. Owing to the irregular topography, the irregular distribution of bedrock and soil mantle, the variable depth of the soil and decomposed granite mantle overlying the bedrock, and the presence of individual water tables, the water level in the Oakhurst-Ahwahnee area is highly variable, ranging from 5 to 75 feet below the the surface. Artesian conditions exist in several wells.

Several flowing wells were noted at apparently random distribution.

Water levels in wells were not monitored in the area; hence, data concerning short-term and long-term trends of water level fluctuations are lacking. Because the water table is generally at a shallow depth, is generally unconfined, and because the ground water storage capacity of the formation is small, it is suspected that water levels respond quickly to precipitation that results in recharge. Most recharge occurs during the winter and spring months when most of the precipitation occurs and the consumptive use by native vegetation is the least. Consequently, water tables rise from November to April or May. Water use is increased, however, from spring through early fall because of higher consumptive use by native vegetation, the increased number of summer residents, and domestic garden irrigation. Toward late summer or early fall, when the water table is at its lowest level, some of the shallow wells go dry. The number of temporary failures among shallow wells may increase substantially during prolonged periods of subnormal precipitation.

Water Well Data

Statistical data concerning well construction practices and well performances were not collected. The following discussions on well data are based upon interviews with local well drillers and the review of the 75 well logs for the area on file with the Department. Most of the wells are used for domestic purposes, few for industrial and municipal purposes. Also, most of the wells were drilled in the topographically subdued lower portion of the valley areas where the bedrock is mantled by a variable depth soil and "decomposed granite" cover.

Wells in the Oakhurst-Ahwahnee area generally are of two types, drilled and dug. Drilled wells are constructed by two methods, rotary drilling and cable-tool (or churn) drilling. It appears that over 90 percent of the wells have been drilled since 1954 and that the majority of them were rotary drilled. Prior to 1954 it is suspected that most of the wells were either drilled by cable-tool equipment or hand dug.

Drilled Wells. Wells can be made much deeper by drilling than they can by hand digging. From the limited data available, it was ascertained that drilled wells range from 34 to 322 feet deep, with the majority ranging from 70 to 140 feet. Well diameters range from 7 to 10 inches. Rotary drilling equipment generally encounters less difficulty in drilling through unweathered bedrock than does cable-tool equipment; this probably accounts for the greater number of rotary drilled wells being constructed in recent years.

A drilled well could obtain its water from both the "decomposed granite" zone and the unweathered rock zone. If the granitic bedrock occurs at a shallow depth, generally less than 30 feet, the casing is extended through the soil and "decomposed granite" and seated into the bedrock. On some occasions the casing is extended to the depth that water is encountered. A drilled well 100 feet or more in depth is not likely to fail during the seasonal dry spell. If the casing in a drilled well is properly seated and grouted by cement or clay, the chance of pollution from surface sources is minimized.

Normal well development consists of washing the hole by circulating water and/or air for a short time to clean the fractures of the drill cuttings. If an insufficient yield is obtained from a well drilled to a predetermined depth, as a last resort the well may be further developed by blasting of the bedrock near the bottom of the well to open existing fractures and initiate new fractures. The success of this method has been spotty. Sometimes, the meager water supply already developed in the well has been lost by this method.

Hand Dug Wells. A hand dug well receives most of its water from the soil and "decomposed granite" zone overlying the granitic bedrock. Much difficulty would be encountered in extending a hand dug well through bedrock, although it has been done to an extent where over half the depth of a few dug wells are in bedrock. Blasting is required in hand digging below bedrock. From the limited data available, it appears that the existing hand dug wells range from 16 to 40.5 feet deep, and average about 25 feet. The diameters of these dug wells range from 4 to 4.5 feet. Under normal casing practices, such wells have a steel casing that extends to a depth of 10 or 15 feet, and the surface area around the casing is grouted with cement. In some instances, casing is not installed.

Hand digging below the water table is difficult; consequently, many of the hand dug wells are not deep enough to provide for natural fluctuations of the water table. Also, where the soil and weathered mantle is thin, the water table may fall considerably below the bedrock level during a dry year, causing the well to fail. The well may have to be temporarily abandoned or be deepened by drilling. For these reasons, hand dug wells are best adapted for sites where the water table is at a shallow depth.

The hand dug well, being of large diameter, has a greater storage capacity than the smaller diameter drilled well. Despite the slow yield from the formation rock, water storage in the well may be sufficient to meet domestic and house garden needs during day use and then recover during the night. Being of shallow depth, hand dug wells are subject to pollution because they are supplied by near-surface water. This should be guarded against by chlorination. Any unchlorinated water supply should be periodically sampled and tested for bacteria.

Water Well Performance. Yields of ground water from fractured crystalline rocks are generally very low, although in some instances flows in fractures encountered in tunnels or mines have been spectacular. Such large flows for sustained periods are the exception in the Oakhurst-Ahwahnee area. According to local well drillers, pump distributors, and the limited data on file, it appears that the yield of wells ranges from one-half to 30 gpm, averaging from about 2 to 5 gpm. The yields from the few flowing artesian wells located within the basin are also reported to be low, not exceeding 30 gpm when pumped. Data on drawdowns are lacking for the area. A 70-foot drawdown and a yield of 4 gpm were recorded for a well located one-half mile west of Oakhurst.

It is suspected that the performances of wells referred to above are not true indications of the productivity of the crystalline rock formation because equilibrium of drawdown is not approached during the pumping operation. In other words, the wells probably could not be pumped continuously at the stated rates. The current well construction practice is to install a submersible pump to a depth of two feet above the bottom of the well. As the drawdown approaches the suction level of the pump during operation, the pump is automatically turned off.

With conservative use of water and employment of a water storage system, it appears at present that wells in the area, despite a generally low yield, usually provide an adequate water supply for domestic needs during periods of normal precipitation.

Selection of Well Sites. As previously mentioned, joints and fractures are the principal controls of movement and storage of ground water in the Oakhurst-Ahwahnee area. Also, joints and fractures are the principal controls of topography since the surface traces of these controlling features have been etched in relief by erosion. Hence, the interpretation of joints and fractures by topographic features can be an aid in selecting apparently favorable well sites. Gulleys, stream valleys, and low, broad valley portions of the basin indicate zones of structural weakness where jointing and fracturing of the rock are most intense. These jointed and fractured areas indicate where rocks are permeable and yield water freely. Wells located in such zones have the greatest possibility of success. The broad low valley areas where a widespread mantle of soil and "decomposed granite" have developed on the bedrock appear to be favorable well sites as demonstrated by the present water development. These low-relief weathered areas are perhaps the more favorable recharge sites. Also, since surface water and ground water move downslope toward these low areas, the water levels tend to be at a shallower depth and do not fluctuate as widely as do those located atop a hill or a ridge.

Hilltops and ridgelines indicate areas of resistant rocks where the frequency of structural rock openings can be expected to be less than in the gulley and valley areas. Water levels on hilltops and ridgelines are generally deeper and tend to fluctuate in a wider range in response to climatic variations.

Municipal-Type Water Development. Because of the low yields of the wells and the previous widely scattered pattern of growth of the area, no extensive municipal water system has been developed. At most, several domestic residences are serviced by a single well. The majority of the new subdivisions do not provide a water service but require each resident to drill a well on each lot. Although the subdivided lots may have all been sold, the actual development and occupancy of the subdivision may occur sporadically over a long period. Perhaps three or four recently developed subdivisions, however, have developed well fields to provide water services for the lots.

Some subdivisions have developed springs to provide a municipal-type water service. Springs are developed by installing large-diameter vertical infiltration wells which are loosely lined with bricks allowing the water to infiltrate them. The water is piped out of these infiltration wells (usually located on hillsides) by gravity into a storage tank located uphill from the subdivision. It was reported that such a system is not entirely satisfactory due to the possibly detrimental effects on this near-surface developed water.

The Royal Oak subdivision, located adjacent to and south of Oakhurst, obtains its water supply from an infiltration gallery-type well situated in the alluvium along the Fresno River. The components of this system include perforated horizontal pipes buried in the pervious alluvium below the water table leading to a central collector well. A chlorination unit is also included. Such a system could develop a water quality problem due to the development of shallow water. This system is reported to be able to yield 165 gpm on a sustained basis.

It appears that within the basin, an infiltration gallery-type well in alluvium would be the only type of large capacity well which could be developed. The optimum capacity of the well would depend upon the extensiveness of the collector galleries and upon the sustained surface and subsurface flow of the stream which recharges the alluvium.

Ground Water Storage and Potential Development

Owing to the meager storage capacity of the fracture opening aquifers, there is a lack of holdover storage from the previous year's precipitation in a developed basin; hence, any one year of subnormal rainfall may cause some shallow wells to go dry. Two or more subnormal precipitation years in succession may cause many shallow wells to go dry. Flows in springs along the streams may also cease or be greatly reduced. A following normal precipitation year may, perhaps, restore ground water to nearly its original level.

Neither the storage capacity of the basin, though small, nor the amount of effluent seepage from springs into the streams could be determined; therefore, the annual quantity of ground water that could potentially be developed, as determined here, is based upon the potential annual recharge from precipitation. The potential recharge was estimated by determining the average amount of precipitation that occurs over the basin from recorded data and by estimating the proportional amount of this precipitation that potentially could seep into the ground as recharge. The average annual precipitation over the basin ranges from 28 inches in the western portion to 45 inches in the higher eastern portion; the overall weighted mean average precipitation over the basin was determined to be 36 inches. It was estimated that 5 percent of the total precipitation could serve as ground water recharge. Stream runoff, evaporation, soil moisture "reservoir", and consumptive use by native vegetation were considered in determining the assumed proportion of potential recharge. The Oakhurst-Ahwahnee basin area is 100 square miles. The amount of ground water recharge was thus calculated to be about 3 billion gallons per year or 9,600 acre-feet per year. The current permanent population in the basin is estimated to be 2,000. If the per capita use of water is 150 gallons per day, the present annual water use is about 110 million gallons per year. This amount is provided almost entirely from ground water. Thus, it is estimated that only a small part of the possible potential annual supply is currently being used. In practice, it is estimated that recovery of the total recharge could not even be approached economically. The calculation above does indicate, however, that it may be possible to develop substantially more ground water than is presently being pumped. Although it is estimated that only a small part of the potential recharge is currently being developed, the lack of year-to-year hold-over storage is due to the limited storage capacity of the fracture openings and to the recharge percolating down gradient and discharging unused into the streams.

It should be noted that fracture opening zones are not continuous and each area may involve individual ground water bodies. Each individual drainage area within the basin represents a subbasin with the crystalline rock drainage divides serving as impermeable barriers. Each major subbasin (major tributary drainage) could be divided into innumerable and still smaller subareas. Since the streams are effluent (where a stream serves as a drain to ground water) ground water recharge along channels of the main drainages is not expected except in local areas where operating wells located close to the stream channel may induce recharge. Ground water recharge to each subarea is dependent upon that precipitation which falls within the individual subarea. Thus, based upon the ground water recharge source being located within the local drainage area, and the very limited ground water storage capacity of the crystalline rocks, a high concentration of water development within a local area cannot be achieved even though the generalized overall basin-wide calculation indicates an apparently sufficient quantity of water.

It should also be noted that the performance of an individual well still depends upon the number of water-bearing fractures encountered. Even though calculations indicate that substantial potential ground water is available, the prospective well may yield an insufficient quantity of water if only a few water-bearing fractures are encountered. The individuality of well performance is a characteristic of a crystalline rock basin.

Another limiting factor of ground water development may be future possible pollution problems in unsewered areas of high urban development. This will be discussed in more detail in the following section under "Water Quality".

Water Quality

Valley Floor Portion

To provide a quality inventory of the water supply available to the Madera area, the Department of Water Resources regularly collects and analyzes samples from representative wells in the valley floor area. In addition, the Department of Water Resources maintains a quality surveillance program on the Chowchilla River, the Fresno River, and the San Joaquin River. During this investigation the quality surveillance program on the San Joaquin River included sampling the river at various locations not only by the Department of Water Resources but also by the U. S. Geological Survey and the U. S. Bureau of Reclamation. The locations of sampling points are shown on Plate 11. Surface water samples collected from eight stations in 1961 were analyzed, and the results are shown in Table 9. Table 10 shows the results of

TABLE 9

ANALYSES OF SURFACE WATER

Date and time sampled P.S.T.	Discharge in cfs	Temp. in °F	Dissolved oxygen ppm	Dissolved oxygen %Sat.	Specific conductance (micromhos) at 25°C	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents	Total dissolved solids in ppm	Per-cent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Turbidity in ppm	Analyzed by[1]
							Mineral constituents in parts per million / equivalents per million																		
San Joaquin River at Friant (Sta. 24)																									
9/6/61 0750	146	52	10.8	97	59	7.3	3.6 / 0.18	1.6 / 0.13	5.4 / 0.23	0.7 / 0.02	0.0 / 0.00	24 / 0.39	0.0 / 0.00	6.0 / 0.17	0.4 / 0.01	0.1 / 0.01	0.1	10	Zn 0.01, PO_4 0.05, ABS 0.0	40	41	16	0	10	USGS
San Joaquin River near Biola (Sta. 24a)																									
9/2-15/61					74	7.1	5.6 / 0.28	1.9 / 0.16	7.0 / 0.30		0.0 / 0.00	28 / 0.45								53	41	22	0		USGS
San Joaquin River at Whitehouse (Sta. 24b)																									
6/2/61 1340	8	73			75	6.7	3.0	2.8	6.9	0.0	0.0	26	3.4	8.2	0.0					48	44				USBR
San Joaquin River near Mendota (Sta. 25)																									
9/6/61 1410	305	78	7.9	96	669	7.8	20 / 1.00	16 / 1.32	85 / 3.70	3.2 / 0.08	0.0 / 0.00	89 / 1.46	41 / 0.85	136 / 3.84	1.0 / 0.02	0.0 / 0.00	0.2	15	Al 0.12, Zn 0.01, PO_4 0.25, ABS 0.0	361	61	116	43	50	USGS
San Joaquin River near Dos Palos (Sta. 25a)																									
9/14/61 1530		74			716	7.9	34	16	80	2.3	0.0	112	50	133	0.0					448	53				USBR
Delta-Mendota Canal near Mendota (Sta. 92)																									
9/6/61 1325		75	7.9	73	695	7.9	21 / 1.05	16 / 1.35	87 / 3.78	4.2 / 0.11	0.0 / 0.00	93 / 1.52	39 / 0.81	137 / 3.86	0.8 / 0.01	0.2 / 0.01	0.1	14	Al 0.06, Cu 0.01, Zn 0.02, PO_4 0.30, ABS 0.0	365	60	120	44	60	USGS
Fresno River near Daulton (Sta. 113)																									
5/10/61 1045	48	65	8.8	93	92	7.5	6.8 / 0.34	2.2 / 0.18	9.1 / 0.40	0.9 / 0.02	0.0 / 0.00	36 / 0.59	0.0 / 0.00	11 / 0.31	0.1 / 0.00	0.1 / 0.01	0.1	20	Al 0.01, PO_4 0.00, ABS 0.0	68	43	26	0	35	USGS
Chowchilla River at Buchanan Dam Site (Sta. 114)																									
5/10/61 1200	8.1	75	8.4	98	315	8.1	25 / 1.25	4.5 / 0.37	31 / 1.35	2.4 / 0.06	0.0 / 0.00	94 / 1.54	3.0 / 0.06	48 / 1.35	0.0 / 0.00	0.1 / 0.01	0.1	24	Al 0.02, PO_4 0.00. ABS 0.0	184	45	81	4	25	USGS

1/ Mineral analyses made by United States Geological Survey, Quality of Water Branch (USGS), and United States Department of the Interior, Bureau of Reclamation (USBR).

TABLE 10

ANALYSES OF GROUND WATER
VALLEY FLOOR UNIT

State Well Number / Date Sampled	Agy. Coll.	Temp. When Sampled °F	pH	Specific Conductance (micromhos at 25° C)	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Carbonate CO_3	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Fluoride F	Boron B	Silica SiO_2	T D S Computed / Evap. 180° C	Total Hardness as $CaCO_3$
					Mineral Constituents in Parts per Million / Equivalents per Million									Mineral Constituents in Parts per Million				
9S/16E-30B3 5-28-64	5050		7.9	201			16 / 0.70					17 / 0.48			0.0			61
-30B3 6-19-62	5050	71	7.9	197	14 / 0.70	6 / 0.48	16 / 0.70	3 / 0.07	0 / 0.00	80 / 1.31	1 / 0.02	18 / 0.51	1.8 / 0.03	0.1	0.06	70	169	59
9S/16E-35N1 8-7-63	5050	72	8.1	285	28 / 1.38	6 / 0.45	27 / 1.17	2 / 0.05	0 / 0.00	127 / 2.09	4 / 0.09	25 / 0.70	4.4 / 0.07	0.1	0.0	39	199 / 192	92
10S/13E-1A1 7-23-63	5641		8.0	490	60 / 3.00	9 / 0.74	39 / 1.70	4 / 0.12	0 / 0.00	223 / 3.65	14 / 0.29	38 / 1.08	27 / 0.44	0.1	0.0	49	351 / 366	187
10S/13E-15A1 10-23-64	5000		7.7	4370					0 / 0.00	93 / 1.52		1390 / 39.21						1590
10S/14E-8B2 5-28-64	5050	67	7.7	594			40 / 1.74					35 / 0.99			0.0			217
-8B2 6-19-62	5050	69	7.7	448	36 / 1.80	10 / 0.86	36 / 1.57	4 / 0.10	0 / 0.00	187 / 3.06	5 / 0.11	33 / 0.93	14 / 0.24	0.1	0.07	68	299	133
10S/14E-11J1 10-22-64	5000		8.5	331					4 / 0.13	151 / 2.47		12 / 0.34						112
10S/14E-13A1 10-22-64	5000		8.3	414					0 / 0.00	138 / 2.26		43 / 1.21						136
10S/14E-19R1 10-7-64	5000	70	8.5	399					4 / 0.13	121 / 1.98		46 / 1.30						95
10S/14E-24B1 8-12-62	5128			802			50 / 2.18	4 / 0.11				136 / 3.84			0.04			261
10S/14E-26H1 10-13-64	5000		8.2	550					0 / 0.00	114 / 1.87		94 / 2.65						173
10S/14E-31H1 11-1-64	5000	69	7.9	1900	137 / 6.84	25 / 2.04	200 / 8.70	4 / 0.12	0 / 0.00	304 / 4.98	43 / 0.90	402 / 11.34	4.2 / 0.07	0.4	0.2	56	1020	195

TABLE 10 (Continued)

ANALYSES OF GROUND WATER
VALLEY FLOOR UNIT

State Well Number / Date Sampled	Agy. Coll.*	Temp. When Sampled °F	pH	Specific Conductance (micromhos at 25° C)	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Carbonate CO_3	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Fluoride F	Boron B	Silica SiO_2	T D S Computed / Evap. 180° C	Total Hardness as $CaCO_3$
					Mineral Constituents in Parts per Million / Equivalents per Million									Mineral Constituents in Parts per Million				
10S/15E-31A1 8-15-63	5050	68		772			43 / 1.87					120 / 3.38			0.10			268
-31A1 7-25-61	5128	72	7.4	662	70 / 3.49	15 / 1.21	38 / 1.65	4 / 0.12	0 / 0.00	187 / 3.06	8 / 0.16	110 / 3.10	7.3 / 0.12	0.1	0.05	72	416	235
10S/16E-30K1 8-28-63	5050	70	8.2	320	31 / 1.53	8 / 0.68	28 / 1.20	2 / 0.06	0 / 0.00	153 / 2.51	4 / 0.09	22 / 0.62	9.7 / 0.16	0.2	0.1	34	215 / 216	110
11S/14E-1A1 3-24-64	5050	66	7.9	931	91 / 4.54	22 / 1.81	64 / 2.78	6 / 0.14	0 / 0.00	318 / 5.21	23 / 0.48	124 / 3.50	7.9 / 0.13		0.0		496 / 563	318
11S/14E-3K1 10-8-64	5000		8.2	1902					0 / 0.00	174 / 2.85		496 / 13.99						685
11S/14E-5B1 8-15-63	5050	68	8.0	610	69 / 3.44	12 / 1.04	36 / 1.55	4 / 0.09	0 / 0.00	110 / 1.80	17 / 0.36	142 / 3.99	3.2 / 0.05	0.1	0.1	57	394 / 412	224
11S/14E-6G1 10-9-64	5000		8.3	2760					0 / 0.00	132 / 2.16		817 / 23.05						896
11S/14E-16A1 9-11-63	5050	70	8.2	655	54 / 2.72	21 / 1.70	40 / 1.75	4 / 0.10	0 / 0.00	137 / 2.25	6 / 0.12	126 / 3.55	11 / 0.18	0.1	0.0	55	385 / 402	221
11S/14E-19B1 9-16-64	5000	65	7.9	2480	132 / 6.59	34 / 2.81	260 / 11.31	3 / 0.08	0 / 0.00	228 / 3.74	105 / 2.19	520 / 14.57	2.3 / 0.04	0.0	0.1	69	1240	283
11S/14E-21N2 10-7-64	5000	67	7.8	7890					0 / 0.00	60 / 0.98		2560 / 72.22						2270
11S/14E-24R1 10-7-64	5000	70	8.3	428					0 / 0.00	146 / 2.39		46 / 1.30						136
11S/14E-28B1 10-7-64	5000	69	8.2	1010					0 / 0.00	75 / 1.23		256 / 7.22						288
11S/15E-6F1 10-8-64	5000		8.6	616					8 / 0.27	172 / 2.82		84 / 2.37						146

TABLE 10 (Continued)

ANALYSES OF GROUND WATER
VALLEY FLOOR UNIT

State Well Number / Date Sampled	Agy. Coll.*	Temp. When Sampled °F	pH	Specific Conductance (micromhos at 25° C)	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Carbonate CO_3	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Fluoride F	Boron B	Silica SiO_2	T D S Computed / Evap. 180° C	Total Hardness as $CaCO_3$
					Mineral Constituents in Parts per Million / Equivalents per Million									Mineral Constituents in Parts per Million				
11S/15E-23L1 8-26-63	5050	69		422			31 1.35					22 0.62			0.0			144
-23L1 7-25-61	5128	73	8.3	365	33 1.65	10 0.83	30 1.30	3 0.07	0 0.00	183 3.00	6 0.12	21 0.59	7.7 0.12	0.2	0.07	71	272	124
11S/17E-25B1 3-19-64	5050	66	8.3	782	61 3.04	22 1.84	70 3.04	3 0.07	4 0.13	376 6.16	19 0.40	49 1.38	2.3 0.04	0.2	0.1	67	482	244
11S/17E-25B1 3-19-64	5050	70	7.2	205			19 0.83		0 0.00	80 1.31		14 0.39			0.0			51
-25B1 6-19-62	5050	71	7.8	197	15 0.75	4 0.29	18 0.78	3 0.08	0 0.00	80 1.31	2 0.03	16 0.45	1.0 0.02	0.1	0.07	68	166	52
11S/18E-17H1 7-25-64	5128		7.7	229	17 0.87	5 0.43	22 0.92	3 0.09	0 0.00	100 1.64	5 0.10	19 0.53	1.0 0.02	0.0	0.00	42	164	65
12S/14E- 3N1 9-23-64	5000	66	8.0	6250	239 11.93	40 3.27	1000 43.50	4 0.09	0 0.00	344 5.64	211 4.39	1680 47.39	7.7 0.12	0.0	0.1	61	3410	760
12S/14E-4J2 10-7-64	5000	66	7.9	5090					0 0.00	173 2.84		1520 42.88						1060
12S/14E-9B1 10-7-64	5000		8.3	706					0 0.00	125 2.05		116 3.27						163
12S/14E-10N1 8-19-63	5050	67		2950			308 13.40					756 21.33			0.1			742
-10N1 7-12-62	5050	67	7.8	2820	217 10.83	29 2.42	353 15.36	7 0.18	0 0.00	125 2.05	220 4.58	773 21.80	2.2 0.04	0.2	0.22	66	1729 1790	663
12S/14E-12N1 10-8-64	5000	68	7.7	2060	113 5.64	34 2.80	260 11.31	2 0.04	0 0.00	296 4.85	84 1.75	452 12.75	1.5 0.02	0.0	0.1	54	1150	422
12S/14E-16K1 7-30-64	5050	69	8.1	836			160 6.96					122 3.44			0.5			34
12S/14E-29B1				1190			160					208			0.4			200

TABLE 13 (Continued)

ANALYSES OF GROUND WATER
VALLEY FLOOR UNIT

State Well Number / Date Sampled	Agy. Coll.*	Temp. When Sampled °F	pH	Specific Conductance (micromhos at 25° C)	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Carbonate CO_3	Bicarbonate HCO_3	Sulfate SO_4	Chloride Cl	Nitrate NO_3	Fluoride F	Boron B	Silica SiO_2	T D S Computed / Evap. 180° C	Hardness as $CaCO_3$
					Mineral Constituents in					Parts per Million / Equivalents per Million				Mineral Constituents in Parts per Million				
12S/14E-29B1 7-7-61	5641		7.6	1160	43 / 2.14	27 / 2.26	154 / 6.70	3 / 0.07	0 / 0.00	113 / 1.85	165 / 3.44	210 / 5.92	0.9 / 0.01	0.2	0.46	43	703	220
12S/15E-27G1 8-15-63	5050	71		381			55 / 2.39					32 / 0.90			0.0			101
-27G1 7-25-61	5128	72	8.1	348	29 / 1.45	5 / 0.39	37 / 1.61	3 / 0.08	0 / 0.00	150 / 2.46	7 / 0.14	29 / 0.82	1.2 / 0.02	0.2	0.05	73	258	92
12S/16E-25P1 7-23-59	5128	72	8.0	243	20 / 1.00	6 / 0.48	25 / 1.09	2 / 0.05	0 / 0.00	121 / 1.98	1 / 0.02	18 / 0.51	1.0 / 0.02	0.2	0.00	84	217	74
12S/17E-5R1 8-13-62	5128	68					17 / 0.74	3 / 0.08				17 / 0.48			0.06			56
-5R1 7-25-61	5128	72	8.0	195	16 / 0.80	3 / 0.28	16 / 0.70	4 / 0.09	0 / 0.00	78 / 1.28	4 / 0.08	17 / 0.48	2.3 / 0.04	0.2	0.05	83	183	54
12S/17E-7L1 8-26-63	5050	69		401			28 / 1.22					25 / 0.70			0.1			127
-7L1 7-25-61	5128	73	8.5	524	50 / 2.50	13 / 1.10	37 / 1.61	5 / 0.13	5 / 0.17	171 / 2.80	63 / 1.31	32 / 0.90	7.4 / 0.12	0.2	0.08	81	378	180
12S/19E-32B1 7-26-61	5128	72	8.0	172	14 / 0.70	4 / 0.34	14 / 0.61	4 / 0.09	0 / 0.00	78 / 1.28	4 / 0.07	8 / 0.22	7.7 / 0.12	0.2	0.06	54	147	52
13S/16E-2C2 8-15-63	5050	71		395			31 / 1.35					19 / 0.54			0.0			130
-2C2 7-25-61	5128	72	8.1	328	28 / 1.40	8 / 0.68	30 / 1.30	2 / 0.05	0 / 0.00	165 / 2.70	5 / 0.10	18 / 0.51	2.7 / 0.04	0.2	0.05	78	253	104
13S/17E-1L1 9-3-63	5000	71	7.4	237	17 / 0.85	5 / 0.44	22 / 0.96	2 / 0.05	0 / 0.00	92 / 1.51	44 / 0.09	23 / 0.65	8.1 / 0.13	0.3	0.0	77	204	65
13S/17E-5P1 3-19-64	5050	78	7.9	530	48 / 2.40	11 / 0.94	47 / 2.04	2 / 0.05	0 / 0.00	218 / 3.57	25 / 0.52	30 / 0.85	18 / 0.29		0.1		290 / 358	167

5000 USGS 5050 DWR 5128 Madera County Farm Adviser 5641 CCID ground water analysis. In addition, numerous surface and ground water samples collected in and near the Madera area have been analyzed and the results published in Bulletins No. 65 and No. 66 series, respectively, of the Department of Water Resources. Beginning in 1963, results of both surface and ground water analyses have been published in the Department's Bulletin No. 130 series.

Surface Water. Streams in the Madera area originate in the Sierra Nevada and drain a predominantly crystalline rock terrane. Runoff is generally of good to excellent quality for most uses. All the streams except the San Joaquin River are intermittent; they are generally dry in their lower reaches during most of the summer each year.

Beginning in 1958, the Chowchilla River was sampled monthly at Buchanan Dam site. In 1962 the sampling point was moved to near Raymond. Since June 1963, samples have been collected twice a year. Analyses of samples indicate the character of the Chowchilla River runoff to be usually a calcium-sodium bicarbonate-chloride type ranging in TDS (total dissolved solids) from 50 to 481 ppm. During the low flow of the fall months, however, the water is generally a sodium-calcium chloride type. Occasionally chloride concentrations rise above the class 1 agricultural limit of 175 ppm. The waters of the Chowchilla River have been within the quality limits for drinking and, with the exception of the occasional above-average chloride concentration have been class 1 for irrigation uses.

The Fresno River is currently being sampled twice yearly near Daulton. Between January 1958 and July 1963, sampling was performed on a monthly basis. The analyses indicate that the character of the water is generally a calcium sodium bicarbonate type. The TDS range from 51 to 231 ppm which is considerably lower in concentration of mineral constituents than are the waters of the Chowchilla River. The quality has been consistently within the recommended limits for domestic and irrigation uses.

The San Joaquin River is currently being sampled four times a year below Friant Dam and monthly below Mendota Dam by the Department. Formerly, water samples were collected from the San Joaquin River by the U. S. Geological Survey near Biola, U. S. Bureau of Reclamation at Whitehouse, and the Department and U. S. Bureau of Reclamation near Dos Palos.

Because of upstream developments the San Joaquin River below Friant Dam does not show seasonal fluctuations in quality that occur in unregulated streams. The water is generally a calcium-sodium bicarbonate type, of consistently good quality, and low in concentrations of mineral constituents. The water has met mineral quality requirements for domestic, irrigation, and most industrial uses. Flows carried in the Madera Canal should be of this same character.

Progressing downstream, the flow in the San Joaquin River begins to decrease because of seepage and evaporation. The quality of the water also becomes slightly degraded.

The water immediately below Mendota Pool is predominantly Delta-Mendota Canal water. From the Mendota Pool to the Merced County line the water becomes degraded by irrigation return flows. The degradation is sufficient to change the quality from class 1 (excellent to good) to class 2 (good to injurious) for irrigation use and to questionable for domestic use. The character of the water in this reach is variable. Sodium and calcium are the predominant cations; the major anions are bicarbonate and chloride. Except during floods, the flow seldom extends to Dos Palos because of influent seepage and diversions.

Ground Water. The character and quality of ground waters in the valley floor are variable. These variables are dependent upon the amount and nature of soluble salts contained in the enclosing sediments, the quality of the surface water available for recharge, the quantity and quality of subsurface waters percolating into the basin, and upon chemical changes that occur (1) as the water percolates through the sediments to the water body and (2) in the ground water reservoir itself. Ground water in the valley floor area of Madera County generally ranges from calcium bicarbonate to a sodium-calcium bicarbonate type, generally of good to excellent quality and suitable for most uses. An exception is a zone of degraded sodium chloride and calcium chloride type waters in the valley trough area between Whitehouse and the Merced County line. The degraded waters are in the perched and in the unconfined and the semiconfined ground water bodies. The changes in character and quality are gradational.

Ground water in the valley floor occurs essentially in three bodies: unconfined and semiconfined, confined, and perched. Lines of equal specific electrical conductivity and areas of similar mineral characteristics for these three zones are shown on Plate 15. Most of the sampled wells pump from the unconfined and semiconfined ground water zone. Very few analyses of ground water in the lower, confined zone are available.

The eastern portion of the valley floor is underlain principally by the old alluvial fan deposits and the Friant Formation. The central portion of the valley floor is underlain predominantly by young alluvial fan deposits and basin deposits. The waters of the unconfined and semiconfined zones in these portions of the Valley are calcium and calcium-sodium bicarbonate in type with specific electrical conductance ranging from 200 to 500 micromhos. Ground waters in these portions of the valley floor are good to excellent for most uses.

Ground water in the valley trough, or western portion of the valley floor, in the unconfined and semiconfined zone is variable in mineral type, ranging in specific electrical conductance from 500 to 1000 micromhos. Within this valley trough area calcium chloride type water occurs in Township 10 and 11 South, Range 14 East, M.D.B.&M.

Variations in the above general character of ground water are in areas along streams, reflecting the recharge from these sources. These variations include a narrow gradational strip of sodium-calcium bicarbonate type water near Madera along the Fresno River and a gradational zone of calcium-sodium bicarbonate type water in the southern portion of the valley floor along the San Joaquin River. The quality represented by these variations is good to excellent for most uses.

Analyses of the confined ground water body beneath the Corcoran clay are available from only two locations: one from the northwestern portion of the valley floor near Red Top, and the other from southwest of Madera. In the area nea Madera, the water is calcium-sodium bicarbonate and sodium-calcium bicarbonate in type with an electrical conductance of about 200 micromhos. The water in the area near Red Top is calcium bicarbonate and sodium-calcium bicarbonate in type with a specific electrical conductance from 300 to 500 micromhos. The quality of the confined water body appears tc be good to excellent and is suitable for most uses. Electric logs of oil wells indicate that the waters contain a higher concentration of salts with increasing depth until connate water is reached in the Tertiary marine sediments, below which the saline water is indigenous to the formation.

The perched or shallow water zone which occurs in the valley trough is highly mineralized, ranging in specific electrical conductance from 750 to 7500 micromhos. The salt accumulation in the soil and subsoils in addition to irrigation return waters probably accounts for this mineralization. The anomalous occurrence of calcium chloride water in the unconfined and semiconfined zone also occurs in the perched zone but is larger in area.

Waste Water and Water Quality Problems. At present almost all wastes in Madera County are disposed of by discharge to land. Some of the activities disposing of waste products are sewage treatment plants, wineries, and food processing plants. Other activities dispose of their wastes by discharge to adjacent surface waters. These are sand and gravel operations and lumber milling.

The only two incorporated cities operating sewage treatment plants are Chowchilla and Madera, which serve a total population of approximately 20,000 people, and which discharge about 3 million gallons of waste water per day to ponds. A large percentage of it is used for irrigation. Winery wastes are disposed of by irrigation, evaporation, or percolation. An olive processing plant located approximately two miles southwest of Madera disposes of its waste by discharge to evaporation and percolation ponds and by discharge to the Madera Sewage Treatment Plant. Several shallow wells in the vicinity of these ponds were abandoned because of mineral degradation which was attributed to percolation from the ponds. Waste discharge requirements established by the Central Valley Regional Water Quality Control Board may alleviate this problem.

Effects of Future Development on Water Quality. In the Madera area, as in all areas of the State, rapid growth and development in all fields of endeavor are desirable. Growth and development may constitute a threat to the quality of both surface and ground waters. Probably the greatest threat to the quality of waters in the Madera area is its pending industrial development. Development and growth in population and recreation also pose a threat to water quality. Suitable controls on the quality of wastes resulting from any of the aforementioned activities should prevent the occurrence of serious problems. The responsibility for exercising these controls is vested in the Central Valley Regional Water Quality Control Board (No. 5).

Several additional water resource development projects are proposed for the Madera area. Among these are the recently authorized Buchanan and Hidden Projects on the Chowchilla and Fresno Rivers, respectively. Other potential prospects under consideration include Chiquito Reservoir on Chiquito Creek and Soquel Meadow Reservoir on North Fork Willow Creek, as well as several other possible alternatives. The construction of the proposed facilities could endanger the water quality through increased recreation activities. Such problems, however, can be prevented or avoided by proper control of waste discharges.

Oakhurst-Ahwahnee Area

The limited number of available mineral analyses of water samples indicates that both surface and ground waters in the Oakhurst-Ahwahnee basin are generally of excellent quality for most beneficial uses. Only spotty and random occurrences of minor water quality problems were noted at the time of this survey (1964). With the anticipation of rapid, urban-type development in localized areas within the basin, future local pollution problems appear imminent if current sewage disposal methods are continued.

Only five random ground water sample analyses are available, three of which were made by the Department of Water Resources and two of which were obtained from a private source. The only quality records of nearby surface waters are the analyses of samples obtained from a Department of Water Resources' sampling station on the Fresno River near Daulton in Section 3, Township 10 South, Range 19 East, M.D.B.&M., approximately 20 miles downstream from the basin surface outlet at Windy Gap. Sampling at this station was initiated in January 1958. The surface water analyses are published regularly by the Department, prior to 1963 in the Bulletin No. 65 series, and since then in the Bulletin No. 130 series. Results of the ground water analyses are shown in Table 11.

Ground Water. Water in the form of rain or snow is almost pure before it falls to the earth. After the water comes in contact with the earth, the chemical quality of the water changes and its resulting character depends upon the amount and nature of soluble salts contained in the rock and upon degradation caused by man-made influences. Oftentimes chemical quality of the water can be surmised by knowing the characteristics of the predominant rock type in which the water is contained. The limited number of chemical analyses of ground water from within the basin, which is predominantly underlain by granitic rock, indicates that the water is of a low concentration calcium bicarbonate type of excellent quality. This is generally consistent with analyses of waters sampled in granitic terranes in other Sierran areas. Of the five samples analyzed, the total dissolved solids ranged from 120 to 289 ppm.

Within a given area, local variations can usually be expected. A sodium chloride type water with total dissolved solids of 289 ppm was noted in well 7S/21E-15A. This variation cannot be readily explained, although waters of this type were noted to occur in springs located in a granitic terrane along Striped Rock Creek, a tributary to the Chowchilla River. These springs are located in the SW$\frac{1}{4}$ of Section 23, Township 7 South, Range 19 East, M.D.B.&M., approximately 8 miles northeast of Raymond. It is suspected that the sodium chloride type water is rising from a great depth and has become greatly diluted by near-surface ground water.

The analysis of a sample from spring 7S/20E-3R indicates that the water is a calcium-magnesium bicarbonate type with total dissolved solids of 216 ppm. This spring is located near Windy Gap in a granitic terrane with nearby outcroppings of pre-Cretaceous metamorphic rocks. It is

TABLE 11

ANALYSES OF GROUND WATER

Upper Madera Unit

Owner	Well number	Date sampled	Specific conductance (micromhos at 25° C)	pH	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)	Boron (B)	Silica (SiO_2)	Other constituents a/	Total dissolved solids in ppm	Percent sodium	Hardness as $CaCO_3$ Total ppm	Hardness as $CaCO_3$ N.C. ppm	Analyzed by b/
					Mineral constituents in parts per million / equivalents per million																	
Elam Ranch (Spring)	7S/20E-3R	9/27/61	320	7.9	33 / 1.65	15 / 1.23	11 / 0.48	2.8 / 0.07	0 / 0.00	181 / 2.97	8.9 / 0.18	4.6 / 0.13	2.0 / 0.03	0.2 / 0.01	0.04	49		216	14	144	0	DWR
H. A. Delany	7S/21E-11L	9/27/61	129	7.6	13 / 0.65	1.1 / 0.09	10 / 0.44	2.7 / 0.07	0 / 0.00	58 / 0.95	0.0 / 0.00	2.3 / 0.06	15 / 0.24	0.2 / 0.01	0.06	48		120	35	37	0	DWR
Royal Oaks Water Co.	7S/21E-11N	4/13/61		7.7	38.7 / 1.93	6.9 / 0.57	27.4 / 1.19		Nil	183 / 3.00	13.6 / 0.28	14.2 / 0.40	Nil		0.2	34.0	Fe=0.12	232	32.3	125		TL
Oakhurst Unified School District	7S/21E-14C	9/27/61	220		17 / 0.85	3.5 / 0.29	20 / 0.87	2.9 / 0.07	0 / 0.00	69 / 1.13	1.6 / 0.03	21 / 0.59	16 / 0.26	0.3 / 0.01	0.14	42		158	42	57	1	DWR
Yosemite Lumber Co.	7S/21E-15A	4/13/61		7.1	27.7 / 1.38	4.9 / 0.40	67.1 / 2.92		Nil	106.8 / 1.75	2.1 / 0.04	102.8 / 2.89	Nil		0.25	24.4	Fe=10.5	288.8	62.1	89.7		TL

a/ Iron (Fe), Aluminum (al), Arsenic (As), Copper (Cu), Lead (Pb), Manganese (Mn), Zinc (Zn), and Chromium (Cr).
b/ Analyzed by Twining Laboratories, Fresno, California (TL) or State Department of Water Resources (DWR) as indicated.

suspected that the higher than normal magnesium content is from the weathering of the ferromagnesian minerals concentrated in the metavolcanic rock unit of the metamorphic rocks.

Surface Water. The surface water chemical composition is expected to be essentially the same as that of the ground water with perhaps a lower concentration during the spring runoff season. During the summer and fall months, the streamflows are sustained by ground water emanating from springs. No analysis of surface water from within the basin is available. Analyses of waters sampled from the Fresno River near Daulton indicate that the waters are a calcium bicarbonate type during the higher spring runoff flows and a calcium-sodium or sodium bicarbonate type during the lower fall and winter runoff flows. The total dissolved solids range from 51 ppm during a period of high runoff to 231 ppm during a period of low runoff.

Water Quality Problems. Although at present the ground water in the Oakhurst-Ahwahnee basin is generally considered to be excellent, local and minor problems have been reported. These include problems concerning iron content, nitrate content, and turbidity. Pollution problems have also been reported in localized areas. A discussion concerning this latter problem is, in part, based upon verbal communications with personnel of the Madera County Health Department in December 1964.

Within the basin, local occurrences of high iron content were reported at random distribution. Iron content determinations were performed on only two samples; concentrations of 10.5 and 0.12 ppm were recorded. An upper limit of 0.3 ppm iron is recommended for drinking water by the U. S. Public Health Service. Where high iron content is discernible -- the water being turbid and rust colored -- it is considered a nuisance to the laundering of clothes because the iron content in the water may preclude the use of chlorine bleach for laundering. It was also reported that colloidal iron had to be removed from the bottom two feet of several of the wells every two years. The source of iron may be finely divided, suspended sediments. Or it may be that the iron is being leached from the "decomposed granite" zone by percolating recharge water.

As noted from the limited available analyses, high concentration of nitrate occurs in two of the five analyses of ground water samples. Of the available analyses, the nitrate concentration ranges from nil to 16 ppm, which is still considered to be within the recommended tolerable upper limit of 45 ppm. The cause or source of this higher than normal nitrate content is not known. Since the nitrate concentration is not accompanied by a high chloride content, it does not appear that the nitrate concentration is derived from organic pollution.

It was reported that in some wells a surge of turbid waters occasionally enters the well during pumping. This is probably caused by an occasional loosening of the clay seams that fill some fractures. It was also reported that the water in some of the wells becomes turbid shortly after a rainstorm. This could be caused by surface water entering the well because the casing is improperly sealed against the formation, or because the casing is not properly seated in bedrock under a mantle of "decomposed granite". It may also indicate that a portion of the water is obtained directly from the surface through open fractures in the decomposed granite zone and this portion of the inflow has not undergoné natural filtration. The turbidity problem can be minimized by extending the casing through the soil and "decomposed granite" zone and properly seating it into the bedrock.

Coliform bacteria have been detected from time to time in various wells, and there is the possibility that with installation of increasing numbers of septic tanks such contamination will occur more frequently. Currently, waste is disposed of by a septic tank system for each individual dwelling and the effluent infiltrates into the "decomposed granite". Some of the sewage undergoes natural filtration as the effluent slowly percolates through the "decomposed granite", whereas some of the effluent may directly recharge the ground water body by flowing along supercapillary fracture openings in the "decomposed granite" and granitic bedrock. The turbid water in some wells after a rainstorm indicates that at least some of the water entering the well from surface sources is not undergoing natural filtration. Within a local area, inclined open fractures or interconnected fracture systems can transmit sewage effluent directly from the leach lines to the lower uncased portion of the well, even though great care is exercised in providing for a sanitary seal in the upper cased portion of the well.

As the area becomes highly developed by urban-type growth, contamination problems may become apparent within the concentrated development and in the areas downslope from the development. The valley trough areas probably would be most susceptible to contamination, especially around Oakhurst where urban-type development occurs upslope in several directions. Also, within this lower valley trough area, the ground water levels are at shallow depths, within five feet of the surface in places. Here sewage disposal could become a serious problem; the infiltration of sewage effluent would not only contaminate the ground waters, which in turn would seep into surface stream waters, but would also build up a ground water mound rising to the surface and causing additional disposal and sanitation problems. Such problems are apparent in local areas of Oakhurst.

Because the streams are sustained by springs during the summer and fall months, surface waters could be contaminated in the future in nearby areas downslope from highly concentrated urban-type developments. Such surface water contamination has been reported in the North Fork area, which is also a granitic rock terrane but outside of the basin, approximately 12 miles southeast of Oakhurst.

At present, it appears for the short-term and middle-term prospects that the future development of the area may be more affected by waste disposal problems than by ground water supply problems. A central sewage disposal system probably would also be necessary in concentrated urban-type development areas.

Interbasin Transfer of Water

Although the area of investigation has no actual water supply imports nor exports, there are several transfers of water from one drainage basin to another. These interbasin transfers of water are discussed in this section.

San Joaquin River Diversions

Madera Canal. Friant Dam on the San Joaquin River near Friant together with Madera and Friant-Kern Canals are owned and operated by the U. S. Bureau of Reclamation as part of its Central Valley Project. Water impounded in Millerton Lake behind this dam is delivered to service areas within the area of this investigation via the Madera Canal and to areas in Tulare Lake Basin to the south via the Friant-Kern Canal.

Water delivered to the Madera Irrigation District and the Chowchilla Water District constitutes an interbasin transfer. During the 6-season base period (April 1, 1952, through March 31, 1958) Madera Canal water diversions to the valley floor portion of Madera area for irrigation and ground water replenishment averaged 214,800 acre-feet annually. The long-term mean supply to these districts from Millerton Lake was assumed to be the estimated average contractual amount. This amount totals 304,000 acre-feet annually, 131,000 acre-feet to the Chowchilla Water District and 173,000 acre-feet to the Madera Irrigation District.

It is estimated that during the six-year base period an average of 36,200 acre-feet of water diverted from Madera Canal flowed out of the area of investigation via the San Joaquin River. Construction of the Hidden and Buchanan

Projects will reduce the loss of this water from the area by providing storage and regulation of river flows and thereby permitting better utilization of Madera Canal supplies. It is estimated that surface outflow of Madera Canal water under long-term mean future water supply conditions with the Hidden and Buchanan Projects in operation will average about 16,000 acre-feet seasonally.

Other Diversions. Numerous other diversions of water from the San Joaquin River into the Madera area are made below Friant Dam. Data on these diversions contained in the Department's Bulletins No. 23-52 through No. 23-58, entitled "Surface Water Flow", indicate that an average of about 70,300 acre-feet annually were diverted into the area during the 6-year base period.

Of this 70,300 acre-feet of water diverted into the area of investigation from the San Joaquin River, it is estimated that about 11,000 acre-feet seasonally returned to the river and left the area as surface outflow. It is believed that under long-term mean future conditions of water supply surface outflow of San Joaquin River diversions will continue to average about 11,000 acre-feet seasonally.

Inasmuch as these diversions are generally based on claimed riparian water rights or contracts with the U. S. Bureau of Reclamation, it is assumed that for the long-term mean water supply conditions this quantity will not change materially.

Big Creek and Soquel Diversions

As mentioned previously there is an existing diversion from Big Creek (a tributary of South Fork Merced River) to the Fresno River Basin. This diversion (dating back to 1888) is made under a water right currently claimed by the Madera Irrigation District and consists of a maximum of 50 second-feet during each month of the year except April when it is reduced to 20 second-feet. There is also an existing diversion dating back to 1897 from North Fork Willow Creek near Soquel Meadow. This diversion is likewise made by Madera Irrigation District under a claimed water right to a maximum of 50 second-feet from October through July of each year.

The quantities of water available to the upper Madera area from these diversions were estimated to ascertain their water development potential. These estimates were based on claimed water rights, existing diversion facilities, recorded diversions for Big Creek since December 1958 and Soquel Creek since November 1960, computed natural flows of Chiquito Creek near Arnold Meadow, and the area-precipitation relationship between the diverted streams and Chiquito Creek. The quantities so determined are not intended to reflect the historical amount of diversion and therefore should not be used to estimate the natural flow of the Fresno River. The estimated quantities of water divertible during the 50-year mean period are shown in Table 12.

Subsurface Flow

Subsurface inflow and outflow contribute to or diminish the water supply available to the valley floor portion of Madera area. These flows may occur under either one or both of two conditions; namely, (1) subsurface flow induced by the difference in the static levels between two points of an aquifer under water table conditions (free ground water body) and (2) subsurface flow caused by the difference in the pressure head between two points in an artesian aquifer (confined water body).

Analysis of available data for the Madera area for the base period led to the following assumptions and conclusions:

1. Subsurface flow would not occur across the ground water mound beneath the San Joaquin River from Friant to the Whitehouse gaging station, in the free ground water body.

2. Seepage losses from the San Joaquin River in the above-mentioned reach would accrue equally to the Madera area and to the Tulare Lake Basin to the south.

3. Subsurface flow across the boundary described above could occur in the confined aquifer.

4. Subsurface flow beneath the San Joaquin River below the Whitehouse gaging station and beneath the Chowchilla River could occur in both the free and confined aquifers.

5. The values computed for the base period subsurface flow would be adequate for the analysis of the long-term mean water supply and present conditions of development; however, the seepage from the San Joaquin River would be reduced from the quantities computed for the base period in proportion to increased diversions via the Friant-Kern and Madera Canals under long-term mean future water supply conditions.

The amount of water contributed to the valley floor portion of Madera area by seepage from San Joaquin River for the base period was computed by subtracting measured surface diversions and estimated evaporation from the difference

TABLE 12

ESTIMATED QUANTITIES OF WATER DIVERTIBLE
BY BIG CREEK AND SOQUEL DIVERSIONS
1907-08 THROUGH 1956-57
(in Acre-feet)

Year	Big Creek Diversion	Soquel Diversion	Year	Big Creek Diversion	Soquel Diversion
1907-08	7,600	7,100	1932-33	6,900	7,300
09	13,100	12,300	34	4,800	4,700
10	10,500	9,600	35	9,400	9,900
1910-11	14,900	14,400	36	9,000	9,600
12	7,000	6,800	37	10,200	10,300
13	6,000	5,900	38	15,000	14,000
14	13,000	12,400	39	5,800	5,900
15	10,200	10,400	40	9,500	9,600
16	12,000	12,300	1940-41	12,600	11,700
17	10,500	10,100	42	11,500	11,100
18	8,000	8,500	43	10,400	10,300
19	7,500	7,300	44	7,700	7,800
20	7,400	7,900	45	11,100	10,500
1920-21	9,200	9,100	46	9,500	9,100
22	10,300	10,200	47	7,400	6,700
23	11,400	10,100	48	6,300	6,800
24	3,700	3,500	49	6,300	7,100
25	7,800	8,000	50	7,200	7,700
26	5,900	6,900	1950-51	10,700	8,600
27	10,100	10,200	52	12,500	11,700
28	7,300	6,900	53	7,100	7,200
29	5,600	6,000	54	6,700	7,400
30	5,400	6,000	55	6,600	6,700
1930-31	3,400	3,600	56	12,400	11,000
32	10,600	10,400	57	7,000	7,000
			Totals	442,000	435,600
			50-year Average	8,840	8,712

between San Joaquin River flows at Friant and at the Whitehouse gaging station. Half of the amount so computed was assumed to contribute to the Madera area. For the long-term conditions, a similar method was used, assuming reduced flow in the San Joaquin River due to increased diversions in the Friant-Kern and Madera Canals. The estimates of inflow to the area from San Joaquin River seepage losses equal 58,000 and 27,200 acre-feet annually for the base period and the long-term mean, respectively.

The procedure used in computing subsurface flows across the boundaries of the valley floor portion of Madera area is outlined below.

1. A baseline was established which approximates the study area boundary for which flow was to be computed.

2. At two-mile intervals along the baseline, cross sections of static water levels were plotted as determined from ground water elevation maps. The slope of each cross section was determined from average elevations two miles from the baseline.

3. A profile along the entire length of the baseline was plotted showing:

   A. Ground surface elevation as determined from topographic maps.

   B. Average elevation of ground water as determined from the cross sections, at the point below the baseline.

   C. Top and bottom of confining aquicludes as determined from geologic cross sections, maps, or other geologic sources.

   D. Elevation of base of main water body or crystalline basement complex as determined from geologic maps.

4. The transmissibility for each township along the baseline was tabulated, and the average transmissibility for each aquifer, or zone, was determined.

5. The cross-sectional area for each two-mile reach along the boundary was determined from the profile.

6. The slope for each cross section was calculated and tabulated.

7. Flow across the baseline reaches was computed from the equation:

$$Q = 3.07 (10^{-6}) p (h/d) lt$$

Where Q is the flow in AF/Day, p is the transmissibility in gal/day/ft^2/100% slope, h/d is the ground water slope in ft/mi, l is the length of the section in miles, t is the thickness of aquifer below the water table, and 3.07 (10^{-6}) is a constant used to convert gallons per day to acre-feet per day.

Estimated long-term mean subsurface flows across these boundaries are based on the premise that the slopes of the water tables across these boundaries will remain about the same in the future as during the base period. Should such prove not to be true, estimated values should be adjusted.

Results of studies of items of supply and disposal by subsurface flow are summarized in Table 13.

TABLE 13

ESTIMATED SUBSURFACE INFLOW AND OUTFLOW
VALLEY FLOOR UNIT
(in Acre-feet per Year)

Item	Madera-Tulare Lake Basin Boundary		Madera-Westside Boundary		Madera-Merced Boundary	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Flow in unconfined aquifer	-	-	2,000	-	-	12,800
Flow in confined aquifer	-	12,300	400	-	-	10,000
Total	-	12,300	2,400	-	-	22,800

Evaporation from Water Surfaces

The average seasonal evaporation from water surfaces on the valley floor portion of the area investigated was estimated by computing the unit seasonal evaporation from representative reservoirs and lake surfaces in acre-feet per acre. This value was then applied to the surface acres of the Madera Canal and rivers within the area as computed from topographic maps and streamflow records. In addition, an allowance was made for evaporation from irrigation systems. The average evaporation thus computed is 1,700 acre-feet seasonally for both the six-year base period and the long-time future water supply conditions.

Flood Problems

The flood plain portions of Madera County were subject to frequent and devastating floods prior to 1941. The uncontrolled runoff of the Chowchilla and Fresno Rivers together with the only slightly regulated flows of the San Joaquin River, aided by the alteration of and encroachment upon the natural stream channels, periodically caused hundreds of thousands of dollars worth of damage to property and crops. Since 1941, however, the flood flows of the San Joaquin River at the foothill line have been regulated through storage in Millerton Lake behind Friant Dam. The State Reclamation Board has been constructing the Lower San Joaquin River Flood Control Project between the Merced River and Gravelly Ford since 1956. Completion of this project together with the regulation provided by Friant Dam will essentially solve the flood problems on the San Joaquin River.

The Chowchilla and Fresno Rivers are still uncontrolled. The U. S. Army Corps of Engineers estimates that annual flood damages will average $690,000 and $705,000 respectively (1965 prices) if remedial measures are not undertak Construction of the Buchanan and Hidden Projects as proposed by the Corps of Engineers and authorized by Congress will solve these flood control problems.

Local flooding of agricultural lands on the valley floor by uncontrolled runoff of relatively small foothill streams such as Dry, Cottonwood, Hildreth, and Root Creeks also occurs. The Soil Conservation Service of the U. S. Department of Agriculture has proposals for the construction of several small dams on the foothill streams to control this local flooding. The dams could be built with federal financing available under the Small Watershed Projects Act.

Although uncontrolled high flows of streams in the mountainous portion of the area of investigation do cause flood damage, the relatively sparse population and limited development of these areas do not justify the construction of flood control projects at this time.

Drainage Problems

A drainage problem may present itself to the farm operator in a number of different forms. It may be an excess accumulation of tail water in the lower part of a field or the presence of a water table within the root zone for an undesirable length of time during the growing season. Also, the internal drainage of the soil in the root zone may be insufficient to prevent water logging of the soil by percolating waters. These conditions may be caused by excess amounts of water applied on the field surface or by the lateral movement of either perched ground water or the main ground water body as a result of irrigation of upslope lands, thereby causing the level of the ground water to rise in lower lying lands.

The reclamation or development of saline soils may lead to drainage problems in some areas due to the application of excess quantities of water at the ground surface in order to leach an accumulation of salts from the root zone. The percolation of the leaching waters may cause the water table to rise, and if tile drains or open ditches are installed, that water which is captured may not be satisfactory for reuse as a water supply.

One measure of an agricultural drainage disposal requirement is that amount of agricultural waste water which may be captured in a drain system and has no further economic value in the area where it is captured. Drainage waters may have no further economic value if they are located in a position such that their use as a water supply is more costly than the development of other water for the supply. If the salt concentration in the drainage water is so great as to make it unfit for use as a water supply and the dilution with better water is infeasible, the drainage water again may be said to have no economic value.

Under natural conditions, many of the soils in the valley basin contain excess salts and alkali and a high water table exists. The salt and alkali conditions generally have created difficult economic problems in cultivation and irrigation. A saline soil is one that contains excess soluble salts. An alkali or sodic soil is one which has about 15 percent or more of sodium ions on the surface of the clay particles. Adequate drainage is required to remove excess soluble salts from the soil and also to permit effective use of calcium amendments to replace the sodium ions in a sodic soil. Leaching of poorly drained areas will improve the soil only to the depth for which adequate drainage can be provided. In areas where there are no significant restrictions to the vertical movement of water in the soil profile, the excess soluble salts may be leached out of the root zone. If the leaching waters with their load of dissolved salts do not move out of the root zone, the salt concentration within the root zone will not be significantly reduced.

In the valley floor of Madera County, many of the soils are dense, slightly permeable, and finely textured; and in places there are cemented subsoils and substrata materials. If natural or artificial drainage is adequate, highly saline soils can be effectively improved by the deep wetting of the soils. The improvement of so-called "alkali" soils is much more difficult because a chemical change must take place within the soil.

A highly saline condition in the soils makes it more difficult for the plant roots to take up water. Also, relative amounts of sodium, magnesium, and calcium in the soil affect soil permeability. The sodium adsorption ratio (SAR) is a measure of the ratio of sodium to calcium and magnesium. In clays, if the proportion of sodium to calcium and magnesium is high, the clay particles tend to disperse and swell when wet. This decreases the pore space and the result is a decrease in permeability and aeration. The particles in the affected soil are packed so closely together that the movement of water and air within the soil is restricted.

In areas where there are cemented substrata, commonly called hardpan, it may be necessary to make some mechanical adjustment in the soil profile by chiseling so as to provide an avenue for the movement of leaching and irrigation waters from the root zone. In areas that have excess alkali problems, it may be necessary to add soil amendments such as gypsum (calcium sulphate) or sulphur.

Drainage problems exist today in the western portion of Madera County within an area bounded on the west by the San Joaquin River and on the east by a line extending generally from the headworks of the Chowchilla Canal to a point in the north at the intersection of the Madera-Merced County line with the San Joaquin River. The drainage problem in this area is one of excessive amounts of water in the soil profile. The salt concentration in the upper 20 feet of the soil profile and in the shallow ground water is relatively low. The salt concentration in the drain water from this area is also relatively low. At the present time, this area is drained by open ditches that discharge into the San Joaquin River. Some of the drain water is reused for irrigation.

The lands immediately to the east, bounded on the west by the present drainage problem area and on the east by the Madera Irrigation District, are sparsely developed for agriculture and irrigation. If these lands can be effectively chiseled in the process of their development for irrigated agriculture, they probably can be leached and irrigated without the immediate development of drainage problems. If the hardpan substratum cannot be leached and effectively chiseled, however, some areas will probably develop perched water tables within a short time after extensive irrigation. Furthermore, as increased amounts of surface water supply are applied on the valley floor of Madera County, drainage problems probably will develop in some areas owing to high water tables. At present, no drainage problem areas are known to exist within the Madera Irrigation District.

In the valley floor portion of Madera County, other than the irrigated strip at the western edge, the present water table is about 20 to 100 feet beneath the ground surface. When the water table is maintained at this depth, drainage problems which may be caused by the high water table of the main ground water body are eliminated. This depth to ground water has developed as the result of pumping the ground water for use as a water supply. If extensive ground water pumping is continued, further drainage problems which might be attributed to a high water table of the main ground water body probably will not occur.

If drainage problems occur in newly developed lands and it becomes infeasible to continue the discharge of drain waters into the San Joaquin River, the San Joaquin Master Drain probably can be used as a means for disposal of the drain waters. The Master Drain will be constructed on the west side of the San Joaquin River in the trough of the Valley. This facility will provide a service for the conveyance of drain waters which have no further economic value to a point of disposal outside of the Valley. This service will be provided to all agricultural areas within the San Joaquin Valley.

Hydrologic Summary

The hydrologic conditions in the valley floor portion of the area are summarized for the six-year base period, and for 1958 conditions of development with long-term mean water supply, in order to determine additional supplemental water requirements. This is done by balancing known items of water supply and disposal. The hydrologic balance was computed by tabulating all known or estimated items of water supply and disposal (except change in ground water storage) as in a balance sheet. The difference between the sum of the supply items and the disposal items then represented the change in ground water storage. If the items of supply exceed those of disposal, a positive change in storage or rise in the water table is indicated, and vice versa.

Base Period

For the six-year base period -- April 1952 through March 1958 -- all the necessary items of supply and disposal together with methods used in computing them have been presented earlier in the report with the exception of consumptive use of applied water. On the basis of land and water use studies, which are reported upon in detail in the next chapter, it is estimated that the average consumptive use of applied water during the base period was about 432,000 acre-feet annually. The hydrologic balance for the base period is shown in Table 14. It will be noted the value computed for change in ground water storage (-67,500 acre-feet) differs by 11,000 acre-feet from the value which was shown in the ground water portion of the report (-56,200 acre-feet) and which was computed independently through the use of ground water measurements and specific yield data. The value computed by the hydrologic balance method, however, is within the limits of error anticipated by the other method of computation. Further, this difference (11,000 acre-feet) is only about 1 percent of either the total supply or the total disposal items and is therefore considered to be within the accuracy of other items of data used.

Although the change in ground water storage as computed above may not constitute an overdraft of the basin *per se*, it does indicate lowering of ground water during the base period. Such a practice if long continued could lower the water table to such an extent that pumping would become uneconomical or could possibly cause serious damage to the ground water basin through the intrusion of poor quality waters from adjacent basins or from deep seated brines. Such an occurrence would then constitute an overdraft on the basin.

Long-term Mean Period

For the long-term mean conditions of supply and 1958 conditions of consumptive use of applied water the following assumptions were made.

1. Precipitation and runoff would be equal to the mean annual values for the historical period 1907-08 through 1956-57.

2. Water deliveries to the Madera area via the Madera Canal would be equal to the long-term contractual class I and average class II values as determined by U. S. Bureau of Reclamation's Millerton Lake operation studies.

TABLE 14

HYDROLOGIC BALANCE--SIX-YEAR BASE PERIOD
APRIL 1952 THROUGH MARCH 1958
VALLEY FLOOR UNIT
(in Acre-feet/Year)

Supply		
Precipitation on Valley Floor	510,400	
Surface Inflow		
Chowchilla River	57,200	
Fresno River	72,600	
Ungaged Minor Streams	8,200	
Madera Canal	214,800	
San Joaquin River Diversions	70,300	
Subsurface Inflow		
Westside Boundary	2,400	
San Joaquin River Seepage	58,000	
Total Supply		993,900
Disposal		
Consumptive Use		
Evaporation from Water Surfaces	1,700	
Precipitation on Valley Floor	498,600	
Applied Water		
Surface Supplies	93,500	
Ground Water	338,700	
Surface Outflow		
Chowchilla River Supply	15,000	
Fresno River Supply	19,800	
Madera Canal Supply	36,200	
San Joaquin River Diversions	11,000	
Precipitation on Valley Floor	11,800	
Subsurface Outflow		
Northern Boundary	22,800	
Southern Boundary	12,300	
Total Disposal		1,061,400
Change in Ground Water Storage		-67,500

3. Subsurface inflow and outflow would be the same as for the 6-year base period.

4. San Joaquin River seepage into the area would be reduced in proportion to the reduction in flow in the San Joaquin River below Friant due to increased deliveries by the Friant-Kern and Madera Canals.

5. Consumptive use of applied water would be the estimated value for 1958 (479,000 acre-feet).

6. Hidden and Buchanan Projects would be built and operated according to the operation studies of the U. S. Army Corps of Engineers.

7. The East Side Division of the Central Valley Project would be built, but no supply from this source would be allotted to the Madera area. This assumption was used, not to imply that no water would be available from this source but because studies by the U. S. Bureau of Reclamation had not advanced to the point of assigning water to specific service areas.

8. Surface outflow of the Fresno River, the Chowchilla River, and the Madera Canal would be equal to the average values computed in the Hidden and Buchanan operation studies.

9. Surface outflow of direct diversions from the San Joaquin River would be equal to that for the base period.

Table 15 shows the hydrologic balance for the long-term water supply under 1958 conditions of consumptive use of applied water. Study of this table discloses that if the Hidden and Buchanan Projects had been built and operating and if the Madera Canal had been delivering the full contractual amount in 1958, ground water storage would have increased by only 9,300 acre-feet. The estimated average consumptive use of water for irrigation of about 222,000 acres in 1958 was about 2.1 acre-feet per acre. Thus, it is apparent that only 4,000 additional acres could be irrigated without depleting the ground water storage even with the Hidden and Buchanan Projects in operation. Continued expansion of irrigated agriculture to the extent projected for the future (315,000 acres by the year 2020) will not be possible without a supplemental source of water. It is estimated that this supplemental requirement would increase from zero in 1960 to about 200,000 acre-feet annually in 2020 in order to prevent a continued drawdown of the ground water basin. None of the projects (Hidden, Buchanan, or East Side

TABLE 15

HYDROLOGIC BALANCE--LONG-TERM SUPPLY TO 2020, 1958 CONDITIONS OF DEVELOPMENT, VALLEY FLOOR UNIT (in Acre-feet/Year)

Item	Amount	
Supply		
Precipitation on Valley Floor	450,300	
Surface Inflow		
Chowchilla River	73,900	
Fresno River	86,100	
Ungaged Minor Streams	7,000	
Madera Canal	304,000	
San Joaquin River Diversions	70,300	
Subsurface Inflow		
Westside Boundary	2,400	
San Joaquin River Seepage	27,200	
Total Supply		1,021,200
Disposal		
Consumptive Use		
Evaporation from Water Surfaces	1,700	
Precipitation on Valley Floor	442,100	
Applied Water		
Surface Supplies	237,300	
Ground Water	241,700	
Surface Outflow		
Chowchilla River Supply	9,100	
Fresno River Supply	9,700	
Madera Canal Supply	16,000	
San Joaquin River Diversions	11,000	
Precipitation on Valley Floor	8,200	
Subsurface Outflow		
Northern Boundary	22,800	
Southern Boundary	12,300	
Total Disposal		1,011,900
Change in Ground Water Storage		+9,300

Division) which could supplement the existing supplies had been started, much less completed, by 1960. The water table will therefore continue to recede until all these projects (or alternatives) are supplying supplemental water to the area.

CHAPTER III. LAND AND WATER USE

Future land use and the water that will be necessary to realize such land use in the Madera area are discussed in this chapter. Estimates of the water required to achieve maximum development are based upon population projections and the capabilities of the land (soil, topography, climate, and crop adaptability) without regard to economics or availability of water. Before any definitive programs to supply the water needs of the County can be completed, it will be necessary to establish the effective demand for water by economic analysis.

The methods and criteria used to determine the potential maximum water requirements of the Madera area are discussed in the following sections.

Study Areas

The Madera County portion of the area of investigation was divided into a Valley Floor Unit and an Upper Madera Unit to facilitate determination of the present and future land and water use. The division between the two units is shown as the foothill line on Plate 1. The Mariposa County portion of the area of investigation in the upper watersheds of the Chowchilla and Fresno Rivers has been designated the Mariposa Unit. These three units, shown on Plate 1, were further subdivided into study areas having one or more common characteristics, such as political structure, serviceability from a common water source, hydrographic unit, or geographic and topographic similarity.

Descriptions of the units, their subdivision into study areas, present source of water supply, and potential methods of fulfilling supplemental water requirements are discussed. The suggested method of meeting the supplemental water requirements is physically and engineeringly feasible; however, economic justification has not been taken into consideration in the following discussions of units.

Valley Floor Unit

The Valley Floor Unit of the Madera area was subdivided into nine study areas numbered 1, 2, and 5 through 11 as shown on Plate 16. Numbers 1 and 2 include the existing Chowchilla Water District and Madera Irrigation District, respectively. The remaining seven areas were delineated because of geographic and topographic similarity and because it is believed that each area could constitute a water service area. The gross area of this unit is nearly 547,000 acres.

Present water supplies for this unit are obtained by diversions from the Chowchilla, Fresno and San Joaquin Rivers, from the Madera Canal of the Central Valley Project, and from the extensively developed underlying ground water. It is believed that future supplemental supplies can best be obtained from the authorized Buchanan and Hidden Projects and the proposed East Side Division of the Central Valley Project.

Upper Madera Unit

This unit encompasses that part of Madera County above the foothill line and was subdivided into nine study areas numbered 12 through 20 as shown on Plate 16. The Upper Madera Unit encompasses about 830,000 acres.

Study Area No. 12, Yosemite-Sierra. The area of about 409,500 acres is entirely within the federal lands of Yosemite National Park and Sierra National Forest. Water requirements in the future, as in the present, probably will be limited to domestic supplies for campgrounds and a few summer homes, and will most feasibly be supplied by local diversion and distribution works.

Study Area No. 13, Oakhurst. The nearly 50,000-acre watershed of the Fresno River within Madera County and above Windy Gap Dam site, including the communities of Sugar Pine, Yosemite Forks, Oakhurst, Ahwahnee, and Nipinnawassee, comprises this study area. Domestic, commercial, industrial, and irrigation water for rural homesites, summer homes, a few small ranches and the above-mentioned communities constitutes the present water requirements. For the most part these requirements are met on an individual basis or by small water development projects through streamflow diversion or shallow wells tapping the relatively limited ground water basins. Future requirements in this area of fairly rapid growth may be met to a limited extent by further exploitation of the local ground water. It is believed, however, that any significant increase in demand would be most economically fulfilled by importation of water from the proposed Soquel Reservoir on North Fork Willow Creek near Soquel Meadow.

Study Area No. 14, Bass Lake. The area encompasses the drainage basin of the North and South Forks of Willow Creek above Crane Valley Dam (Bass Lake Reservoir) and has an area in excess of 52,000 acres. The area is entirely within Sierra National Forest but contains the relatively well-developed community of Bass Lake as well as several other small residential developments. In addition, there are numerous campgrounds, many of which have no developed water supply at present. Present water requirements are primarily for domestic and recreation purposes and consist of relatively small local surface water developments. Future supplemental requirements probably will be of the same nature as at present and can best be met by a combination of individual local developments for isolated areas and releases from the proposed Soquel Reservoir. The Bass Lake residential, commercial, and recreation requirements would be served by a pipeline from a small diversion dam on the North Fork Willow Creek which would divert releases made from Soquel Reservoir.

Study Area No. 15, North Fork. This study area encompassing the drainage basin of Willow Creek (both the North and South Forks) between Bass Lake and the San Joaquin River, contains nearly 34,000 acres. Although this area is almost entirely within Sierra National Forest, it does contain the communities of North Fork and South Fork and scattered individual residences (primarily along Mammoth Road) which have consumptive water requirements. In addition, nonconsumptive facilities of Pacific Gas and Electric Company, consisting of dams, reservoirs, powerplants, tunnels, pipelines, and conduits located between Crane Valley Dam and the San Joaquin River, develop the power potential of water stored in Bass Lake. Present requirements for consumptive use (primarily domestic with limited industrial) are supplied by individual wells and mutual water companies. Any significant supplemental water requirements probably can be supplied by a proposed pipeline from Manzanita Lake to the communities of North Fork and South Fork. Manzanita Lake, in turn, could be replenished by releases from the proposed Soquel Reservoir.

Study Area No. 16, Fine Gold. This subunit contains the watersheds of Fine Gold Creek and several other small creeks between Kerckhoff and Millerton Lakes on the San Joaquin River. The area, containing about 86,500 acres, is sparsely populated and relatively undeveloped. Individual wells provide the major part of the limited water requirements for the small community of O'Neals and the scattered residences. Future supplemental supplies, if significant, probably could be provided by a dam and reservoir on Fine Gold Creek.

Study Area No. 17, Hidden. This subunit is made up of the watershed of the Fresno River between Windy Gap Dam site and the foothill line and includes almost 82,000 acres. The area is sparsely populated with very little agricultural development. The small community of Coarsegold on Highway 41 is the only population center. Present water requirements are fulfilled by individual wells or small ponds. Supplemental water supplies could be provided to the vicinity of Coarsegold by a pipeline from the proposed Soquel Project.

The lower portion of this subunit could be supplied by a pumped diversion from Hidden Reservoir which would be within the subunit.

Study Area No. 18, Raymond. This study area, encompassing about 30,000 acres, includes the drainage basins of the several small foothill streams between the Fresno and Chowchilla Rivers lying above the foothill line. The two small communities of Raymond and Knowles together with a few small ranches and isolated homesites constitute the present developments requiring water. In general, these needs are met through individual wells or small farm ponds. Supplemental requirements could be met by increased private development and, if significant, augmented by pumping directly from Chowchilla or Fresno Rivers, or alternatively by pumping from Buchanan or Hidden Reservoirs.

Study Area No. 19, Buchanan. The 48,000-acre watershed of the Chowchilla River above the foothill line and lying within Madera County constitutes Study Area No. 19. This area, sparsely populated and agriculturally undeveloped, would contain Buchanan Reservoir. Present water requirements are met by ground water pumping and small surface water developments. In the future, supplemental water probably will continue to be supplied as at present. In addition, water supplies could be pumped from the Chowchilla River either directly or from Buchanan Reservoir.

Study Area No. 20, Belleview. The subunit includes the watersheds of foothill streams (primarily Hildreth and Cottonwood Creeks) between the Fresno and San Joaquin Rivers and above the foothill line. Within this 38,000-acre area are found the San Joaquin Experimental Range, a few ranches, and scattered residences but no communities. As in most of the other subunits, present water supply developments are individual enterprises consisting of wells and small farm reservoirs. Future requirements probably will be met by similar means. Because of the extreme scarcity of surface runoff during dry years and the high rate of surface evaporation, there appears to be little opportunity for any significant quantities of water to be developed by local projects. The possible exception would be pumping from the San Joaquin River or Millerton Lake.

Mariposa Unit

The Mariposa Unit includes the watersheds of the Chowchilla and Fresno Rivers above the foothill line and outside of Madera County. The unit, encompassing 128,000 acres, has been subdivided into four subunits designated Study Areas 21 through 24 as shown on Plate 16.

Study Area No. 21, Happy Camp. This relatively small subunit, containing only about 7,000 acres, comprises the watershed of the Fresno River lying within Mariposa County. The area is entirely within Sierra National Forest. Present, and probably future, water requirements, met by small individual developments of surface waters, are limited to domestic supplies for campgrounds and possibly summer homes.

Study Area No. 22, Upper Chowchilla. Study Area No. 22, encompassing about 44,000 acres, is made up of that part of the drainage basin of the Chowchilla River north of the Mariposa-Oakhurst Road (State Highway 49). Several small residential communities lie within or along the southern boundary of this subunit, namely Darrah, Bootjack, Usona, and Elliott Corner. In addition, several areas are in the process of being subdivided for homesites. This area, encompassing the headwaters of the West, Middle, and East Forks of the Chowchilla River, contains most of the attractive mountain homesites within the area of investigation outside of Sierra National Forest. Present water requirements (primarily domestic) are met by pumping from the small ground water basins and by a few small ponds. Future supplemental requirements probably can be met by some increase in ground water extraction and individual reservoirs, augmented if necessary by construction of a dam and reservoir on the Middle Fork Chowchilla River near Usona.

Study Area No. 23, Lower Chowchilla. This subunit, containing about 52,000 acres, is bounded on the north by the Mariposa-Oakhurst Road, on the northwest by the Chowchilla watershed divide, on the southwest by the 1500-foot contour and Split Rock Creek, and on the southeast by the Mariposa-Madera County line. Other than those along the northern boundary referred to in the previous paragraph, there are no significant communities in the area. The area is sparsely populated along the road between Bailey Flats and Usona; otherwise, it is little developed either residentially or agriculturally. Present water requirements are met on an individual basis, usually by shallow wells tapping the local ground waters. Supplemental water required for future growth probably can be developed by a limited increase in ground water exploitation and, if necessary, by a dam and reservoir project on the West Fork Chowchilla River near Wildcat Mountain.

Study Area No. 24, Oakvale. This area, containing about 25,000 acres, comprises the watershed of the Chowchilla River in Mariposa County lying between Study Area No. 23 and the foothill line. The subunit at present is relatively undeveloped with the exception of scattered residences along the roads traversing the area. The present and future water requirements are and probably will be met by individual wells. If a significant increase in water is required, it could be provided by pumping from the Chowchilla River or Buchanan Reservoir.

Land Use

Predictions of the future water use depend upon estimates of future land use within the Madera area. Projections were, therefore, made of population growth and of agricultural, municipal, recreational, and industrial developments.

Land use and land classification surveys were made for the Valley Floor Unit in 1958 and 1960, respectively; Upper Madera Unit in 1961 and 1962, respectively; and the Mariposa Unit in 1959.

Population

Predictions of the urban, suburban, rural nonfarm and farm population were made for the Valley Floor Unit. No attempt was made to make this differentiation in the Upper Madera and Mariposa Units. Population figures for 1960 are based upon reports of the United States Bureau of Census. Projections for year 2020 are based upon estimates of the Department of Water Resources for Mariposa and Madera Countie Population projections for the various subunits were made to reflect the effects of existing and proposed water developmen

The population predictions are shown by decades for the Valley Floor Unit in Table 16, and for years 1960 and 2020 for the Upper Madera Mariposa Units in Table 17.

Land Classification

As an aid to land use predictions, lands of the are of investigation were segregated into the following categorie on the basis of the land classification surveys.

1. Irrigable agricultural

2. Irrigable forest and range

3. Urban and suburban

TABLE 16

ESTIMATED PERMANENT POPULATIONS BY DECADES, 1960-2020
VALLEY FLOOR UNIT

Land Use	Study Area Number									Unit Total
	1	2	5	6	7	8	9	10	11	
U,S&RN*	5,633	15,710	1,815	1,522	34	1,486	434	446	1,984	29,064
Farm	827	1,440	1,014	1,063	25	1,107	324	326	898	7,024
Total	6,460	17,150	2,829	2,585	59	2,593	758	772	2,882	36,088**
U,S&RN	6,900	19,200	2,200	1,800	50	1,800	500	500	2,400	35,350
Farm	800	1,500	1,000	1,100	50	1,100	300	300	900	7,050
Total	7,700	20,700	3,200	2,900	100	2,900	800	800	3,300	42,400
U,S&RN	9,500	26,700	2,600	2,200	50	2,200	600	600	3,100	47,500
Farm	1,000	1,700	1,200	1,200	50	1,300	400	400	1,000	8,250
Total	10,500	28,400	3,800	3,400	100	3,500	1,000	1,000	4,100	55,800
U,S&RN	14,400	42,500	4,700	4,000	50	3,900	1,100	1,100	5,300	77,050
Farm	1,200	2,100	1,500	1,600	50	1,700	500	500	1,300	10,450
Total	15,600	44,600	6,200	5,600	100	5,600	1,600	1,600	6,600	87,500
U,S&RN	21,300	63,300	6,700	5,600	100	5,500	1,600	1,600	7,500	113,200
Farm	1,200	2,000	1,500	1,500	100	1,600	500	500	1,300	10,200
Total	22,500	65,300	8,200	7,100	200	7,100	2,100	2,100	8,800	123,400
U,S&RN	32,600	97,900	9,100	7,700	100	7,500	2,200	2,200	10,900	170,200
Farm	1,000	1,800	1,200	1,300	100	1,400	400	400	1,100	8,700
Total	33,600	99,700	10,300	9,000	200	8,900	2,600	2,600	12,000	178,900
U,S&RN	47,100	143,200	11,700	9,800	250	9,600	2,800	2,900	14,800	242,150
Farm	900	1,600	1,100	1,200	50	1,200	400	400	1,000	7,850
Total	48,000	144,800	12,800	11,000	300	10,800	3,200	3,300	15,800	250,000

n, Suburban, and Rural Nonfarm.
Bureau of Census Population Figures.

TABLE 17

ESTIMATED PERMANENT POPULATION IN 1960 AND 2020
IN UPPER MADERA AND MARIPOSA UNITS

Study Unit	1960	2020
Upper Madera Unit		
No. 12	100	200
No. 13	1,500	15,000
No. 14	400	2,000
No. 15	1,100	3,500
No. 16	250	1,100
No. 17	400	2,500
No. 18	400	1,000
No. 19	100	100
No. 20	130	500
Subtotal	4,380	25,900
Mariposa Unit		
No. 21	25	130
No. 22	360	1,900
No. 23	85	400
No. 24	50	270
Subtotal	520	2,700

4. Recreation

5. Major park

6. All other

Irrigable Agricultural Lands. Irrigable agricultural lands are classified according to the slope and soil characteristics. Both slope and related soil factors directly affect the degree of suitability of the lands for irrigation and were the primary consideration in establishing the "land class"; i.e., the maximum potential use of the land. In predicting the future land use -- particularly in the case of irrigable agricultural lands -- the foregoing factors were considered but were modified by additional analysis of economic factors related to crop production and the location of land with respect to the water supply.

Topographic characteristics of irrigable agricultural lands are identified in the tables of this bulletin by the following symbols:

V - These lands are level or slightly sloping and range from smooth to hummocky or gently undulating relief. The maximum allowable slope is six percent smooth, reasonably large bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes are limiting. These lands are suitable for all climatically adapted crops.

H - These are lands with greater slope and/or relief than those of the V class. They range from smooth to moderately rolling or undulating relief. The maximum allowable slope is 20 percent for smooth, reasonably large bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes are limiting.

M - These are lands with greater slope and/or relief than those of the H class. They range from smooth to steeply rolling or undulating relief. The maximum allowable slope is 30 percent for smooth, reasonably large bodies lying in the same plane. As the relief increases and becomes more complex, lesser slopes are limiting.

Irrigable agricultural lands identified as V, H, or M contain permeable soils with medium to deep effective root zones. They are free of rock and not limited by a high water table. Variations from this pattern are identified in the tables of this bulletin by the following symbols:

l - Fairly coarse textures and low moisture-holding capacities, which in general make these lands unsuited for the production of shallow-rooted crops because of the frequency of irrigation required to supply the water needs of such crops.

p - Shallow depth of effective root zone; crops limited to those with shallow roots.

r - Sufficient rock to prevent crop cultivation.

w - High water table; land use limited to pasture crops unless drainage and a change in irrigation practice increase its adaptability to other types of crops.

Even in the most intensively developed areas of irrigated agriculture, not all areas classified as irrigable agricultural lands would receive water every year. The gross irrigable areas were, therefore, reduced for the following reasons:

1. Farmers would limit production on lands having limited adaptability and productivity to periods when economic conditions are favorable.

2. Crop rotation and fallowing would reduce the extent of irrigated land.

3. Farmsteads, industries, and rights-of-way, such as roads, railroads, and canals, would occupy irrigable acreage.

4. Certain nonirrigable lands occur within lands classified as irrigable because the area involved is too small to delineate.

5. Small, irregularly shaped plots of land, isolated by ownership or location from larger units of irrigable land, would be irrigated less readily than the larger units.

In the Valley Floor Unit, 206,000 acres of the gross irrigable lands for the above reasons would be devoted to non-agricultural uses by the year 2020. Net irrigated acreages, therefore, would be about 315,000 acres.

Estimates indicate that in the Upper Madera and Mariposa Units about 67 percent, or 24,700 acres, and 70 percent, or 29,000 acres, respectively, of the gross irrigable agricultural lands could be devoted to agricultural uses. For the above reasons, it is doubtful if this use will ever closely approach 100 percent.

Irrigable Forest and Range Lands. These lands are presently forested or subjected to forest or range management. They possess the slope and soil characteristics of irrigable agricultural lands but, because of conditions of climate and location, are best suited to remain under some type of forest or range management program.

Urban and Suburban Lands. These lands may be irrigable or nonirrigable. Irrigable lands classified as potential urban and suburban lands possess the characteristics of irrigable agricultural lands (V, H, or M) but most likely will be used to absorb urban and suburban expansion brought about by the anticipated increase in California population. Estimates of population in the Valley Floor, Upper Madera, and Mariposa Units in the year 2020 (Tables 16 and 17) were used to help determine the amount of land classified as potential urban and suburban land. The following categories were used to identify urban and suburban lands.

1. Urban (city, town, small community) lands; presently developed for commerce, industry, and residences.

2. Potentially urban (city, town, small community) lands; probable intense future development for commerce, industry, and residences.

3. Suburban and potentially suburban lands; low density of residences; little or no commerce or industry.

The main purpose in the determination of land categories 2 and 3 was to indicate those irrigable lands of the area which urban encroachment would render unavailable for agriculture by the year 2020. Estimates of water use on these lands by the year 2020 are based on predicted population rather than on area.

Recreation Lands. These consist of lands presently or potentially characterized by fairly intensive recreation development requiring water service. The classification does not include those high mountainous lands intensively used for recreation by hunters and fishermen. Estimates of future population expansion (Tables 16 and 17) and recognition of the increasing demand for recreation areas helped determine the acreage classified as potential recreation land. Estimates indicate that land so classified will be developed to its full potential by the year 2020. Computation of water use in recreation lands is based on predicted population rather than on area. The following categories of recreation lands are identified in the tables of this bulletin.

1. Existing and potential permanent and summer home tracts.

2. Existing and potential commercial areas (motels, resorts, hotels, stores etc.).

3. Existing and potential camp and trailer sites.

Category 1 lands subdivide according to their probable density of development; fewer houses per acre, for example, will be built on hilly land than on flat land. Calculations of the density of development of the recreation-oriented lands provided a basis for predicting water use and requirements by the year 2020.

Major Park Lands. These lands use little water and consist of existing county, state, and federal parks, race tracks, and fairgrounds.

All Other Lands. The classification consists of all lands not included in one of the five previous designations. Table 18 shows all 6 designations and lists by units the acreage within each classification in the Valley Floor, Upper Madera, and Mariposa Units.

Present Land Use

Patterns of land use that existed during the land use surveys referred to earlier are presented in Table 19.

The predominant use of land in the Valley Floor Unit is for irrigated agriculture, while in the other two units, urban, suburban, and recreation purposes constitute the larges use of land. It is expected that this distribution will continue in the future.

Future Land Use

Because of the importance of irrigated agriculture in the Valley Floor Unit, irrigated acreages were projected on a decadal basis from 1960 through 2020. Ten crops of economic importance to the area were individually projected for each of the nine study areas in order to estimate future water requirements. The ten crops used in these projections are grain, rice, cotton, sugar beets, miscellaneous field crops, alfalfa, pasture, miscellaneous truck crops, deciduous orchard, grapes, and subtropical orchard. A summary of the crop projections by decades for the Valley Floor Unit is presented in Table 20. The total irrigated acreage shown is that of the major crops and does not include the acreages double cropped and shown as the minor crops.

TABLE 18

CLASSIFICATION OF LANDS OF THE MADERA AREA
VALLEY FLOOR UNIT
(in Gross Acres)

Land Class	Study Area Number 1	2	5	6	7	8	9	10	11	Unit Totals
Irrigable Agricultural										
V	19,540	69,160	13,800	3,250	1,030	12,230	580	2,900	9,770	132,260
Vw	-	-	220	150	-	-	-	-	-	370
Vl	-	270	60	-	240	620	-	-	50	1,240
Vp	9,070	16,370	450		300		1,400	7,200	34,910	69,700
Vr	-	-	-	-	-	-	-	-	-	-
Vs	22,570	13,260	17,790	20,270	-	20,550	60	80	900	95,480
Vpr	-	-	-	-	-	-	-	-	-	-
Vps	5,340	4,180	2,740	3,450	-	90	-	-	60	15,860
Vss	2,520	1,940	11,860	15,280	-	-	-	10		31,610
Vpss	1,880	1,700	16,920	16,280	-	-	-	-	-	36,780
Vsa	240	60	430	4,740	-	-	-	-	-	5,470
Vpsa	120	240	15,030	15,910	-	-	-	-	-	31,300
Vm	-	-	330	30	-	-	-	-	-	360
H	50	60		70	50	500	10	190	2,080	3,010
Hw	-	-	-	-	-	-	-	-	-	-
Hl	-	-	-	-	10	-	-	-	-	10
Hp	90	190	-	-	-	45,730	11,840	12,820	17,840	88,510
Hr										
Hpr	-	-	-	-	-	-	-	100	-	100
M	-	-	-	-	-	20	-	40	-	60
Mw	-	-	-	-	-	-	-	-	-	-
Mp	-	70	-	-	-	1,910	2,810	2,640	1,100	8,530
Mr	-	-	-	-	-	-	-	-	-	-
Mpr	-	-	-	-	-	-	200	10	-	210
Subtotals	61,420	107,500	79,630	79,430	1,630	81,650	16,900	25,990	66,710	520,860
Irrigable Forest and Range Lands	-	-	-	-	-	-	-	-	-	-
Urban and Suburban	990	2,810	50	30	-	250	-	-	970	5,100
Recreation Lands										
Summer Home Tracts	-	-	-	-	-	-	-	-	-	-
Commercial	-	-	-	-	-	-	-	-	-	-
Campgrounds and Trailer Parks	-	-	-	-	-	-	-	-	-	-
Subtotals	-	-	-	-	-	-	-	-	-	-
Major Parks	50	80	-	-	10	-	-	-	780	920
All Other Lands	1,770	1,980	1,480	600	690	2,760	4,700	4,550	1,490	20,020
TOTALS	64,230	112,370	81,160	80,060	2,330	84,660	21,600	30,540	69,950	546,900

TABLE 18 (Continued)

CLASSIFICATION OF LANDS IN THE MADERA AREA
UPPER MADERA UNIT
(in Gross Acres)

Land Class	Study Area Number									Unit
	12	13	14	15	16	17	18	19	20	Totals
Irrigable Agricultural										
V	20	350	130	30	70	50	10		70	730
Vw	1,710	60	270	60	-	-	-	-		2,100
Vl	-	10	-	-	40	-	-	-	-	50
Vp	-	-	-	-	-	-	-	-	20	20
Vr	-	-	20	-	-	20	-	-	-	40
Vs	-	-	-	-	-	-	-	-	-	-
Vpr	-	-	-	-	-	-	-	-	-	-
Vps	-	-	-	-	-	-	-	-	-	-
Vss	-	-	-	-	-	-	-	-	-	-
Vpss	-	-	-	-	-	-	-	-	-	-
Vsa	-	-	-	-	-	-	-	-	-	-
Vpsa	-	-	-	-	-	-	-	-	-	-
Vm	80	-	10	-	-	-	-	-	-	90
H	40	670	10	110	540	90	230	90	-	1,780
Hw	250	10	40	10	-	-	-	-	-	310
Hl	-	-	-	-	-	-	-	-	-	-
Hp	-	-	80	560	1,310	70	120	20	500	2,660
Hr	-	1,480	-	-	340	1,950	100	1,110	100	5,080
Hpr	-	-	-	-	470	410	460	360	770	2,470
M	20	540	-	40	50	-	-	-	-	650
Mw	40	-	-	-	-	-	-	-	-	40
Mp	-	100	60	1,760	4,190	110	2,300	110	850	9,480
Mr	-	700	-	-	-	200	-	240	-	1,140
Mpr	-	-	-	180	1,950	2,270	1,340	1,500	3,390	10,630
Subtotals	2,160	3,920	620	2,750	8,960	5,170	4,560	3,430	5,700	37,270
Irrigable Forest and Range Lands	13,050	-	1,070	560	-	90	-	40	-	14,810
Urban and Suburban	20	490	10	320	60	50	90	-	30	1,070
Recreation Lands										
Summer Home Tracts	210	2,850	670	320	-	-	-	-	-	4,050
Commercial	40	30	40	-	-	-	-	-	-	110
Campgrounds and Trailer Parks	3,290	110	550	90	90	-	-	-	-	4,130
Subtotals	3,540	2,990	1,260	410	90	-	-	-	-	8,290
Major Parks	77,710	-	-	40	-	-	-	-	-	77,750
All Other Lands	313,040	42,410	49,150	29,900	77,420	76,570	25,420	44,580	32,740	691,280
TOTALS	409,520	49,810	52,110	33,980	86,530	81,880	30,070	48,050	38,470	830,420

TABLE 18 (Continued)

CLASSIFICATION OF LANDS OF THE MADERA AREA
MARIPOSA UNIT AND SUMMARY
(in Gross Acres)

Land Class	Mariposa Unit: Study Area Number 21	22	23	24	Summary: Mariposa Unit Totals	Valley Floor Unit Totals	Upper Madera Unit Totals	Area Totals
Irrigable Agricultural								
V		170	130	-	300	132,260	730	133,290
Vw	60	90	-	-	150	370	2,100	2,620
Vl	-	-	-	-	-	1,240	50	1,290
Vp	-	-	-	-	-	69,700	20	69,720
Vr	-	-	-	-	-		40	40
Vs	-	-	-	-	-	95,480	-	95,480
Vpr	-	-	10	-	10	-	-	10
Vps	-	-	-	-	-	15,860	-	15,860
Vss	-	-	-	-	-	31,610	-	31,610
Vpss	-	-	-	-	-	36,780	-	36,780
Vsa	-	-	-	-	-	5,470	-	5,470
Vpsa	-	-	-	-	-	31,300	-	31,300
Vm	-	-	-	-	-	360	90	450
H	-	3,960	1,390	110	5,460	3,010	1,780	10,250
Hw	-	-	-	-	-	-	310	310
Hl	-	-	-	-	-	10	-	10
Hp	-	960	880	2,260	4,100	88,510	2,660	95,270
Hr	-	10	20	-	30	-	5,080	5,110
Hpr	-	980	1,780	590	3,350	100	2,470	5,920
M	-	1,660	200	-	1,860	60	650	2,570
Mw	-	-	-	-	-	-	40	40
Mp	100	3,490	2,410	3,510	9,510	8,530	9,480	27,520
Mr	-	-	90	-	90	-	1,140	1,230
Mpr		4,510	8,800	3,540	16,850	210	10,630	27,690
Subtotals	160	15,830	15,710	10,010	41,710	520,860	37,270	599,840
Irrigable Forest and Range Lands	-	-	-	-	-	-	14,810	14,810
Urban and Suburban	-	-	-	-	-	5,100	1,070	6,170
Recreation Lands								
Summer Home Tracts	3,420	390	-	-	3,810	-	4,050	7,860
Commercial	10	-	-	-	10	-	110	120
Campgrounds and Trailer Parks	70	60	-	-	130	-	4,130	4,260
Subtotals	3,500	450	-	-	3,950	-	8,290	12,240
Major Parks	-	-	-	-	-	920	77,750	78,670
All Other Lands	3,760	27,670	36,200	14,770	82,400	20,020	691,230	793,650
TOTALS	7,420	43,950	51,910	24,780	128,060	546,900	830,420	1,505,380

TABLE 19

PRESENT PATTERN OF LAND USE IN MADERA AREA
VALLEY FLOOR UNIT
(in Acres)

Land Use	Study Area Number 1	2	5	6	7	8	9	10	11	Unit Totals
Agricultural										
Irrigated:										
Grain	2,160	3,170	3,590	1,060	-	220	-	-	820	11,020
Rice			2,100	40	-	-	-	-	-	2,140
Cotton	13,920	19,420	7,020	4,000	160	460	-	30	1,090	46,100
Sugar Beets	90	640	2,440	860	-	-	-	-	-	4,030
Misc. Field	12,310	9,890	2,370	2,670	60	580	-	-	1,070	28,950
Alfalfa	8,600	12,330	7,010	5,940	30	410	-	90	420	34,830
Pasture	15,140	10,720	6,480	8,540	130	1,600	-	60	5,430	48,100
Misc. Truck	410	3,970	1,030	520	10	30	-	-	-	5,970
Misc. Deciduous	1,360	3,870	200	-	250	420	-	70	1,420	7,590
Vineyard	150	24,490	-	240	470	710	50	-	90	26,200
Fallow	1,800	7,310	5,970	3,940	80	1,630		20	2,180	22,930
Subtotals	55,940	95,810	38,210	27,810	1,190	6,060	50	270	12,520	237,860
Nonirrigated:										
Grain	2,580	2,880	-	-	90	30,460	2,090	6,570	26,090	70,760
Meadow Pasture	-	-	-	-	-	-	-	-	-	-
Subtropical	-	-	-	-	-	-	-	-	-	-
Misc. Deciduous	-	-	-	-	-	-	-	-	-	-
Fallow	560	2,520	-	-	30	27,410	1,610	6,460	18,990	57,580
Subtotals	3,140	5,400	-	-	120	57,870	3,700	13,030	45,080	128,340
Urban and Suburban	1,810	4,180	430	180	80	240	40	30	920	7,910
Recreational	-	-	-	-	-	-	-	-	-	-
Summer Homes	-	-	-	-	-	-	-	-	-	-
Commercial	-	-	-	-	-	-	-	-	-	-
Campgrounds	-	-	-	-	-	-	-	-	-	-
Subtotals	-	-	-	-	-	-	-	-	-	-
Major Parks	-	-	-	-	-	-	-	-	-	-
All Other Lands	3,340	6,980	42,520	52,070	940	20,490	17,810	17,210	11,430	172,790
TOTALS	64,230	112,370	81,160	80,060	2,330	84,660	21,600	30,540	69,950	546,900

TABLE 19 (Continued)

PRESENT PATTERN OF LAND USE IN MADERA AREA
UPPER MADERA UNIT
(in Acres)

Land Use	Study Area Numbers 12	13	14	15	16	17	18	19	20	Unit Totals
Agricultural										
Irrigated:										
Grain	-	-	-	-	-	-	-	-	-	-
Rice	-	-	-	-	-	-	-	-	-	-
Cotton	-	-	-	-	-	-	-	-	-	-
Sugar Beets	-	-	-	-	-	-	-	-	-	-
Misc. Field	-	-	-	-	-	-	-	-	-	-
Alfalfa	-	-	-	-	-	-	-	-	-	-
Pasture	20	160	-	-	10	10	-	-	-	200
Misc. Truck	-	-	-	-	-	-	-	-	-	-
Misc. Deciduous	-	-	-	10	-	-	-	-	-	10
Vineyard	-	-	-	-	-	-	-	-	-	-
Fallow	-	-	-	-	-	-	-	-	-	-
Subtotals	20	160	-	10	10	10	-	-	-	210
Nonirrigated:										
Grain	-	70	-	40	90	-	50	10	60	320
Meadow Pasture	2,010	70	310	70	-	-	-	-	-	2,460
Subtropical	-	-	-	-	-	-	110	-	-	110
Misc. Deciduous	40	60	20	-	10	-	-	-	-	130
Fallow	-	-	-	-	-	-	-	-	-	-
Subtotals	2,050	200	330	110	100	-	160	10	60	3,020
Urban and Suburban	20	610	10	350	60	70	90		110	1,320
Recreation										
Summer Homes	60	320	380	80	-	-	-	-	-	840
Commercial	40	30	40	-	-	-	-	-	-	110
Campgrounds	250	20	230	50	90	-	-	-	-	640
Subtotals	350	370	650	130	90	-	-	-	-	1,590
Major Parks	77,710	-	-	-	-	-	-	-	-	77,710
All Other Lands	329,370	48,470	51,120	33,380	86,270	81,800	29,820	48,040	38,300	746,570
TOTALS	409,520	49,810	52,110	33,980	86,530	81,880	30,070	48,050	38,470	830,420

TABLE 19 (Continued)

PRESENT PATTERN OF LAND USE IN MADERA AREA
MARIPOSA UNIT AND SUMMARY
(in Acres)

Land Use	Mariposa Unit				Summary			
	Study Area Number				Mariposa Unit Totals	Valley Floor Unit Totals	Upper Madera Unit Totals	Totals
	21	22	23	24				
Agricultural								
Irrigated:								
Grain	-	-	10	-	10	11,020	-	11,030
Rice	-	-	-	-	-	2,140	-	2,140
Cotton	-	-	-	-	-	46,100	-	46,100
Sugar Beets	-	-	-	-	-	4,030	-	4,030
Misc. Field	-	10	-	-	10	28,950	-	28,960
Alfalfa	-	-	-	-	-	34,830	-	34,830
Pasture	-	80	30		110	48,100	200	48,410
Misc. Truck	-	-	-	-	-	5,970	-	5,970
Misc. Deciduous	-	320	10	-	330	7,590	10	7,930
Vineyard	-	-	-	-	-	26,200	-	26,200
Fallow	-	-	-	-	-	22,930	-	22,930
Subtotals	-	410	50	-	460	237,860	210	238,530
Nonirrigated:								
Grain	-	20	10	90	120	70,760	320	71,200
Meadow Pasture	60	80	-	-	140	-	2,460	2,600
Subtropical	-	-	-	-	-	-	110	110
Misc. Deciduous	10	20	-	-	30	-	130	160
Fallow						57,580	-	57,580
Subtotals	70	120	10	90	290	128,340	3,020	131,650
Urban and Suburban	-	-	-	-	-	7,910	1,320	9,230
Recreational								
Summer Homes	-	-	-	-	-	-	840	840
Commercial	10	-	-	-	10	-	110	120
Campgrounds	30	10	-	-	40	-	640	680
Subtotals	40	10	-	-	50	-	1,590	1,640
Major Parks	-	-	-	-	-	-	77,710	77,710
All Other Lands	7,310	43,410	51,850	24,690	127,260	172,790	746,570	1,046,620
TOTALS	7,420	43,950	51,910	24,780	128,060	546,900	830,420	1,505,380

TABLE 20

SUMMARY OF CROP PROJECTIONS BY DECADES, 1960-2020
VALLEY FLOOR UNIT
(in Acres)

Crop	1960	1970	1980	1990	2000	2010	2020
ajor Irrigation Season							
Deciduous Orchard	7,602	9,100	10,600	12,000	13,600	15,000	16,500
Grapes	26,195	27,900	29,500	31,100	32,800	34,400	36,100
Cotton	46,107	49,700	53,200	56,900	60,500	64,200	67,800
Miscellaneous Truck	5,983	6,600	7,200	7,800	8,400	9,000	9,600
Sugar Beets	4,028	4,800	5,500	6,200	7,000	7,800	8,500
Miscellaneous Field	39,097	39,000	39,000	39,000	39,000	39,000	38,800
Alfalfa	34,816	34,300	33,900	33,600	33,300	33,000	32,500
Pasture	49,227	53,500	58,000	62,400	66,800	71,500	76,100
Rice	2,152	2,200	2,300	2,300	2,400	2,500	2,500
Fallow	14,461	16,500	18,600	20,600	22,600	24,600	26,600
Total Land Acres Irrigated	229,668	243,600	257,800	271,900	286,400	301,000	315,000
inor Irrigation Season							
Grain	16,100	20,000	23,900	27,700	31,700	35,400	38,900
Miscellaneous Field	1,700	2,800	3,900	5,000	6,100	7,200	8,200
Miscellaneous Truck		500	1,000	1,500	2,000	2,400	2,700
Subtotal	17,800	23,300	28,800	34,200	39,800	45,000	49,800
otal Crop Acres Irrigated	247,468	266,900	285,800	306,100	326,200	346,000	364,800

Table 21 summarizes the estimated irrigated acreages for each of the nine study areas for the period 1960-2020 by ten-year increments.

Crop projections for the Upper Madera and Mariposa Units were limited to the three types of irrigated crops of commercial significance to the areas. These crops include pasture, alfalfa, and deciduous orchard. The potential acreages of these crops in the year 2020 were estimated under the premise that water would be made available at a cost within the ability of the users to pay. Such would probably not be the case because of the scattered land locations, the limited quantities of water available for development, and the high cost of developing and delivering agricultural water. The estimated acreages of irrigated crops in 1960 are shown in Table 22, and the potentially irrigable acreages in 2020 are shown in Table 23.

A significant portion of the future homesites in the upper area will include gardens and home orchards. Therefore, estimates of the acreage of homesites in the year 2020 were made.

Water Use

Unit Water Requirements

As mentioned previously, to estimate water requirements it is necessary to have, in addition to population estimates and projected land use, unit values of consumptive use of applied water. Irrigation requirements are based on the application of water that exceeds precipitation. In other words, these are the irrigation requirements that must be met by irrigation methods, whether it be by flooding, furrow, or sprinkler; by use of ground water, surface water, or a combination of both. The irrigation requirement is expressed in acre-feet per acre per year.

For domestic, commercial, and industrial use the requirements are based on studies of the actual use of water for these purposes at present and an evaluation of current trends to predict further use. Because of the continued increase in the rate of water use for these purposes, it is believed that future unit requirements will be higher than present requirements. For this study the commercial and industrial requirements have been placed under the general heading of domestic requirements because there are only two incorporated cities in the area and their commercial and industrial water is generally supplied by the domestic water supply systems. The domestic water requirements are based upon the population estimates and are usually expressed in gallons per capita per day (gpcd).

TABLE 21

ESTIMATED IRRIGATED ACREAGE BY DECADES, 1960-2020
VALLEY FLOOR UNIT
(in Acres)

Study Area No.	1960	1970	1980	1990	2000	2010	2020
1	55,569	54,400	53,100	51,900	50,600	49,300	48,000
2	94,882	92,000	89,300	86,500	84,000	81,400	79,000
5	36,124	40,900	45,800	50,700	55,600	60,700	65,400
6	25,335	31,100	36,900	42,600	48,500	54,600	60,500
7	1,187	1,200	1,300	1,300	1,300	1,400	1,500
8	5,263	8,800	12,400	16,000	19,600	23,100	26,500
9	45	300	500	800	1,000	1,200	1,400
10	271	1,100	2,000	2,900	3,800	4,600	5,400
11	10,992	13,800	16,500	19,200	22,000	24,700	27,300
Total	229,668	243,600	257,800	271,900	286,400	301,000	315,000

TABLE 22

ESTIMATED 1960 IRRIGATED ACREAGE
IN UPPER MADERA AND MARIPOSA UNITS
(in Acres)

Study Area No.	Commercial			
	Orchard	Alfalfa	Pasture	Total
Upper Madera Unit				
No. 12			20	20
No. 13			160	160
No. 14				
No. 15	10			10
No. 16			10	10
No. 17			10	10
No. 18				
No. 19				
No. 20				
Subtotal	10		200	210
Mariposa Unit				
No. 21				
No. 22	320	10	80	410
No. 23	20		30	50
No. 24				
Subtotal	340	10	110	460
Total	350	10	310	670

TABLE 23

ESTIMATED POTENTIALLY IRRIGABLE[1] ACREAGE IN
UPPER MADERA AND MARIPOSA UNITS
(in Acres)

Study Area No.	Commercial: Orchard	Commercial: Alfalfa	Commercial: Pasture	Commercial: Subtotal	Homesite: Garden & Orchard	Total
Upper Madera Unit						
12	40	30	2,020	2,090	10	2,100
13	480	180	1,170	1,830	500	2,330
14	100	20	390	510	-	510
15	300	40	1,160	1,500	115	1,615
16	1,100	130	5,050	6,280	55	6,335
17	460	40	2,910	3,410	125	3,535
18	510	50	2,530	3,090	50	3,140
19	290		1,960	2,250	5	2,255
20	520	20	3,180	3,720	25	3,745
Subtotal	3,800	510	20,370	24,680	885	25,565
Mariposa Unit						
21			120	120	5	125
22	450	150	10,580	11,180	95	11,275
23	340	150	10,360	10,850	20	10,870
24	870	120	5,900	6,890	15	6,905
Subtotal	1,660	420	26,960	29,040	135	29,175
Total	5,460	930	47,330	53,720	1,020	54,740

1/ Based upon the premise that water would be made available within the ability of users to pay.

Estimates of unit water requirements may be expressed as consumptive requirements and as applied water requirements. As implied by its name, a consumptive requirement is the water that is used directly: (1) by an entity itself (whether it be plant, animal, or manufactured goods), (2) through evaporation, or (3) through transpiration. Because no use of water is one hundred percent efficient, the applied water requirement is greater than the consumptive use. In fact it is necessary to apply more irrigation water than is required for consumptive use to prevent excessive salinity in the root zone of the plants because: (1) all natural waters contain dissolved salts, (2) plants utilize very little of these salts in their consumption of water, and (3) the salts are left in the root zone in concentrations in nearly inverse proportion to the complement of the irrigation efficiency.

$$\text{Root zone concentration} \simeq \frac{\text{original concentration}}{1.0 - \text{efficiency}}$$

Therefore, in determining the unit values of irrigation water requirements for the Madera area, the unit values of consumptive use of applied water were estimated on the basis of land and water use studies and then divided by the estimated efficiency which would be applicable to obtain the unit value of irrigation water requirement. The efficiency of domestic use is assumed to be 50 percent. For irrigated agriculture a separate efficiency was developed which represents good farming practice for each of the major crops expected to be grown in the area. Over the entire area, however, the average irrigation efficiency used is about 75 percent. Owing to wide differences in crop patterns and precipitation, separate unit irrigation water requirement values were developed for the Valley Floor Unit and for the upper units. Table 24 shows the unit values of consumptive use of applied and irrigation water requirement in the Madera area.

Likewise, different unit values of domestic water requirements were used because of the wide range in commercial and industrial developments and in population densities in the area of investigation. These variations, however, are not directly related to the geography or topography of the area but rather to the location of population centers.

For the City of Madera it was assumed that throughout the period 1960-2020 the present rate of water use would remain unchanged at about 364 gpcd. In the remainder of the Valley Floor Unit it was assumed that the unit value of applied domestic water requirements would continue to increase during the period to about 344 gpcd by 2020. In the foothill and mountainous units, because of the limited water available and the higher cost of obtaining it, a constant rate of 220 gpcd was assumed for the applied water requirement.

TABLE 24

ESTIMATED UNIT VALUES OF CONSUMPTIVE USE
OF APPLIED AND IRRIGATION WATER REQUIREMENTS
IN MADERA AREA
(in Acre-feet per Acre per Year)

Crop	Unit Consumptive Requirement	Unit Applied Water Requirement
Valley Floor Unit		
Grain	0.5	0.7
Cotton	2.2	2.9
Sugar Beets	1.8	2.6
Alfalfa	2.9	3.6
Pasture	2.9	3.9
Deciduous Orchard	2.0	2.5
Grapes	2.1	2.6
Rice	4.1	6.8
Miscellaneous Field	1.2	1.6
Miscellaneous Truck	1.0	1.3
Upper Madera and Mariposa Units		
Pasture	2.4	3.7
Alfalfa	2.1	3.0
Deciduous Orchard	1.8	2.6
Homesite Garden and Orchard	2.1	3.2

Annual Water Requirements

Having the population estimates, projected land use, and unit water requirements, it is possible to compute the amounts of water necessary to meet the annual requirements for irrigation and domestic purposes. Because of the importance of the development of the Valley Floor Unit to the economy of Madera County and because of the greater probability of economic justification and financial feasibility of water development projects for this unit, annual water requirements were computed on a decadal basis for the period 1960-2020. For the other two units the requirements were computed for 1960 and 2020 only, because of the uncertainty of the rate of development and the questionability of economic water development projects. Therefore, the estimates of water requirements for the upper area must be considered to be potential rather than probable.

Table 25 summarizes the annual consumptive water requirements for irrigation and domestic purposes for the Valley Floor Unit by decades. The annual applied water requirements are likewise summarized for the Valley Floor Unit in Table 26.

Because the amount of water used for irrigation of homesite gardens and orchards is more nearly dependent upon population than upon agricultural development, water for these purposes has been considered as a part of the domestic supply for the Upper Madera and Mariposa Units. Therefore, the water requirements estimated for irrigation in these units do not include homesite garden and orchard requirements.

For the upper units of the area of investigation the annual irrigation and domestic water requirements, both consumptive and applied, for 1960 and 2020 are shown in Table 27. As previously explained, the year 2020 potential irrigation water requirement is a measure of the capability of the lands and climate rather than an indication of availability of water. The requirement is based upon the potential for use rather than the economic demand. The irrigable lands are in small, widely scattered parcels, however, and the water available for development is limited and would be expensive to develop. It is doubtful, therefore, that the economic demand for irrigation water from the water development projects will justify such development in the year 2020. In fact, our studies disclosed only about 100 acres that might be able to support irrigation from a specific water supply project. This one instance is possible only because the lands lie below and adjacent to a proposed domestic supply pipeline and have a repayment capacity higher than the average for the upper units.

The domestic water requirements for 2020 shown in Table 27 are believed to be a realistic estimate for the future. It is believed that individual wells will continue

TABLE 25

ESTIMATED CONSUMPTIVE USE OF APPLIED WATER BY DECADES, 1960-2020
VALLEY FLOOR UNIT
(in Acre-feet per Year)

Study Area	1960	1970	1980	1990	2000	2010	2020
Study Area No. 1							
Irrigation	121,600	118,600	115,400	112,400	109,300	106,100	103,000
Domestic	750	950	1,400	2,350	3,850	6,300	9,250
Subtotal	122,350	119,550	116,800	114,750	113,150	112,400	112,250
Study Area No. 2							
Irrigation	195,300	189,800	184,700	179,600	174,800	170,100	165,800
Domestic	3,150	3,850	5,450	8,650	12,900	20,000	29,450
Subtotal	198,450	193,650	190,150	188,250	187,700	190,100	195,250
Study Area No. 5							
Irrigation	78,300	89,000	99,900	110,700	121,600	132,600	143,100
Domestic	250	350	450	850	1,300	1,800	2,450
Subtotal	78,550	89,350	100,350	111,550	122,900	134,400	145,550
Study Area No. 6							
Irrigation	59,700	72,000	84,200	96,600	109,000	122,100	134,600
Domestic	250	300	400	800	1,100	1,550	2,100
Subtotal	59,950	72,300	84,600	97,400	110,100	123,650	136,700
Study Area No. 7							
Irrigation	2,500	2,500	2,500	2,600	2,700	2,900	3,000
Domestic*	-	-	-	-	-	-	-
Subtotal	2,500	2,500	2,500	2,600	2,700	2,900	3,000
Study Area No. 8							
Irrigation	11,200	19,300	27,200	35,200	43,200	51,100	58,800
Domestic	250	300	450	800	1,100	1,550	2,100
Subtotal	11,450	19,600	27,650	36,000	44,300	52,650	60,900
Study Area No. 9							
Irrigation	100	600	1,200	1,700	2,200	2,700	3,200
Domestic	100	100	100	200	350	450	600
Subtotal	200	700	1,300	1,900	2,550	3,150	3,800
Study Area No. 10							
Irrigation	700	2,200	3,800	5,300	6,900	8,500	10,000
Domestic	100	100	100	200	350	450	650
Subtotal	800	2,300	3,900	5,500	7,250	8,950	10,650
Study Area No. 11							
Irrigation	25,000	31,800	38,600	45,300	52,200	58,900	65,300
Domestic	300	350	500	900	1,400	2,100	3,050
Subtotal	25,300	32,150	39,100	46,200	53,600	61,000	68,350
Valley Floor Unit Total							
Irrigation	494,400	525,800	557,500	589,400	621,900	655,000	686,800
Domestic	5,150	6,300	8,850	14,750	22,350	34,200	49,650
Total	499,550	532,100	566,350	604,150	644,250	689,200	736,450

*Less than 50 acre-feet.

TABLE 26

ESTIMATED APPLIED WATER REQUIREMENTS BY DECADES, 1960-2020
VALLEY FLOOR UNIT
(in Acre-feet per Year)

Study Area	1960	1970	1980	1990	2000	2010	2020
Study Area No. 1							
Irrigation	159,800	155,800	151,700	147,800	143,700	139,600	135,400
Domestic	1,500	1,900	2,800	4,700	7,700	12,600	18,500
Subtotal	161,300	157,700	154,500	152,500	151,400	152,200	153,900
Study Area No. 2							
Irrigation	251,500	244,100	237,300	230,600	224,200	217,900	212,100
Domestic	6,300	7,700	10,900	17,300	25,800	40,000	58,900
Subtotal	257,800	251,800	248,200	247,900	250,000	257,900	271,000
Study Area No. 5							
Irrigation	106,000	120,200	134,700	149,200	163,700	178,400	192,400
Domestic	500	700	900	1,700	2,600	3,600	4,900
Subtotal	106,500	120,900	135,600	150,900	166,300	182,000	197,300
Study Area No. 6							
Irrigation	78,400	93,100	111,100	127,600	144,100	161,600	178,300
Domestic	500	600	800	1,600	2,200	3,100	4,200
Subtotal	78,900	93,700	111,900	129,200	146,300	164,700	182,500
Study Area No. 7							
Irrigation	3,200	3,100	3,200	3,300	3,400	3,600	3,800
Domestic*	-	-	-	-	-	-	-
Subtotal	3,200	3,100	3,200	3,300	3,400	3,600	3,800
Study Area No. 8							
Irrigation	14,700	25,300	35,700	46,300	56,800	67,300	77,400
Domestic	500	600	900	1,600	2,200	3,100	4,200
Subtotal	15,200	25,900	36,600	47,900	59,000	70,400	81,600
Study Area No. 9							
Irrigation	100	800	1,500	2,200	2,900	3,500	4,100
Domestic	200	200	200	400	700	900	1,200
Subtotal	300	1,000	1,700	2,600	3,600	4,400	5,300
Study Area No. 10							
Irrigation	900	2,900	4,900	6,900	9,000	11,100	13,100
Domestic	200	200	200	400	700	900	1,300
Subtotal	1,100	3,100	5,100	7,300	9,700	12,000	14,400
Study Area No. 11							
Irrigation	33,100	42,200	51,200	60,100	69,200	78,100	86,600
Domestic	600	700	1,000	1,800	2,800	4,200	6,100
Subtotal	33,700	42,900	52,200	61,900	72,000	82,300	92,700
Valley Floor Unit Total							
Irrigation	647,700	687,500	731,300	774,000	817,000	861,100	903,200
Domestic	10,300	12,600	17,700	29,500	44,700	68,400	99,300
Total	658,000	700,100	749,000	803,500	861,700	929,500	1,002,500

*Less than 100 acre-feet.

TABLE 27

ESTIMATED 1960 AND POTENTIAL[1/] 2020 CONSUMPTIVE AND APPLIED WATER REQUIREMENTS
IN UPPER MADERA AND MARIPOSA UNITS
(in Acre-feet per Year)

Unit	1960				2020			
	Irrigation[2/]		Domestic[3/]		Irrigation[2/]		Domestic[3/]	
	Consumptive	Applied	Consumptive	Applied	Consumptive	Applied	Consumptive	Applied
Upper Madera								
Study Area No. 12	50	75	15	25	5,020	7,670	45	80
No. 13	385	595	190	375	4,100	6,120	3,225	5,965
No. 14	-	-	50	100	1,200	1,760	250	500
No. 15	20	25	140	275	3,440	5,190	735	1,355
No. 16	25	40	35	65	14,510	21,940	250	450
No. 17	25	40	50	100	7,970	12,080	625	1,175
No. 18	-	-	50	100	7,150	10,840	230	410
No. 19	-	-	15	25	5,270	8,010	25	40
No. 20	-	-	20	35	8,690	13,180	165	205
Upper Madera Unit Subtotal	505	775	565	1,100	57,350	86,790	5,550	10,180
Mariposa								
Study Area No. 21	-	-	5	10	290	440	30	55
No. 22	800	1,155	45	90	26,720	40,770	460	840
No. 23	110	160	10	20	25,980	39,670	90	160
No. 24	-	-	10	15	16,120	24,450	60	110
Mariposa Unit Subtotal	910	1,315	70	135	69,110	105,330	640	1,165

1/ Based upon the premise that water would be made available within the ability of users to pay.
2/ Does not include requirements for homesite irrigation of gardens and orchards.
3/ Includes requirements for homesite irrigation of gardens and orchards and for commercial establishments.

to meet water requirements in sparsely populated areas where it may not be feasible to provide service from proposed surface water developments.

CHAPTER IV. PLANS FOR DEVELOPMENT

The overall objective of the Department of Water Resources is to provide guidance and leadership in planning for and implementing the orderly development of water resources to meet the economic and social needs of the people of California. To assure such development in an efficient and effective manner, planning studies are scheduled well in advance of project construction. The Madera Area Investigation is a reconnaissance study for initiating the development of future water projects.

During this investigation many possible water projects were studied to assure the selection of projects best suited to serve the needs of the area. Two multiple-purpose projects appear superior to possible alternatives. The proposed Oakhurst-Soquel Project would be located in the Oakhurst-Bass Lake area, and the proposed Upper San Joaquin River Project would be located in the Minarets Region of the upper San Joaquin drainage basin tributary to Mammoth Pool Reservoir. Additional studies would be required to clearly demonstrate economic justification, financial feasibility, and the best method of implementing these projects.

Studies were made of a possible project to develop surface runoff to supply water to the major areas of urban and rural residential growth in the Mariposa unit. A dual-purpose project for domestic water supply and recreation was considered, as well as a single-purpose project for domestic water supply only. The project found most advantageous was a dual-purpose project, designated the "Usona Project", on the Middle Fork Chowchilla River about a mile north of Bootjack Road. Major project features would include a dam creating a 4,000 acre-foot reservoir with a normal pool elevation of 3,048 feet, pipelines to convey water to the general area of Usona, Elliot Corners and Lush Meadow Estates, and initial recreation facilities to accommodate 42,000 visitor-days annually. At the present time this project does not appear economically justified because of the high cost of reservoir yield and the small demand for water during the early years of the project.

Population projections for the Mariposa unit indicate that the water requirement would be only 70 acre-feet in 1970 but would increase to 585 acre-feet by 2020. In the future, however, if water users are capable of paying more for water than believed to be feasible at present, or if the population increases more rapidly than predicted, the project may become economically justified. The Usona Project is not presented in this report because of the apparent lack of economic justification. Information on the project may be obtained from the San Joaquin District Office.

Under the statewide water resources investigation conducted between 1947 and 1957 by the Department of Water Resources, information was gathered and studies were made which led to the formulation of the California Water Plan. Proposed projects presented in Bulletin No. 3, "The California Water Plan", included some proposals for future development of water resources of Madera County, and were described as components of the plan for the San Joaquin-Sierra Group. Proposed works included the following:

Hidden Reservoir
Buchanan Reservoir
Windy Gap Reservoir
Miami Creek Reservoir
Lewis Fork Reservoir
Nelder Creek Reservoir
Mammoth Pool Reservoir and Powerplant
Chiquito Creek Reservoir and Powerplant
Miller Bridge Reservoir and Powerplant
Forks Reservoir and Powerplant

Review of Previous Proposals

A review during the Madera Area Investigation of projects proposed under the California Water Plan revealed that some proposed projects should be eliminated and others should be modified. Rapid growth taking place in the vicinity of Oakhurst would make acquisition of land for some projects too costly. Studies also proved that other proposals should be modified. For example, it was found that a large dam and reservoir constructed at Jackass Meadow, although not previously proposed, could develop the waters of Granite and Jackass Creeks for power by direct diversion to Forks Reservoir on the San Joaquin River rather than through proposed Chiquito Reservoir on Chiquito Creek.

The current (1965) appraisals of previously proposed projects are described in the following sections.

Hidden Reservoir

This authorized project on the Fresno River is to be constructed by the U. S. Army Corps of Engineers.

Floods of the Fresno River are uncontrolled, and the Corps of Engineers estimates that future flood damages would average about $705,000 per year (1965 prices) if no further protection were provided. These damages would occur mostly in the general vicinity of the City of Madera. This area is also water deficient, and there is an urgent need for irrigation water supplies which could result from the storage and regulation of flood flows. There is also need for additional outdoor recreation opportunities, such as boating, water skiing, fishing, swimming, and picnicking which could be provided by facilities associated with water storage and conservation. For these reasons the Corps of Engineers has planned a multiple-purpose project on the Fresno River for control of floods, development of irrigation water, and provision of recreation facilities.

A dam constructed on the Fresno River about 14 airline miles northeast of the City of Madera would impound 90,000 acre-feet of water in Hidden Reservoir. The reservoir would regulate flood flows and other inflows for release as safe channel flood releases and irrigation releases. Recreation facilities would be provided at the reservoir. The first cost of the dam and reservoir and recreation facilities would be about 13.5 million dollars.

The Sacramento District Office is now (1965) preparing plans and specifications for the Hidden Project. Contingent upon congressional appropriations, construction of the dam and the recreation facilities will probably commence in 1968 and be completed in 1970. The Division of Forestry, Calif. Dept. of Conservation, has cooperated with the Corps of Engineers in the preparation of fire prevention plans for the Hidden and Buchanan Projects.

Buchanan Reservoir

This authorized project on the Chowchilla River is to be constructed by the U. S. Army Corps of Engineers.

The Chowchilla River floods valley lands along the Chowchilla and San Joaquin Rivers, including the City of Chowchilla. Future damages would average $690,000 annually (1965 prices) if no provisions were made for controlling such floods. Large areas of irrigable lands capable of high productivity cannot be fully developed because of the scarcity of irrigation water. The increase in population in this area and other parts of California have created a need for development of water-associated recreation facilities. The Corps of Engineers has formulated a multiple-purpose project for the control and development of the water resources of the Chowchilla River at the proposed Buchanan site.

Construction of a dam at the Buchanan site about 16 miles northeast of the City of Chowchilla would provide 150,000 acre-feet of storage space. This storage would be used for multiple purposes, including flood control, conservation, and recreation. Floods would be regulated by placing flood flows in storage and releasing at rates within the capacities of downstream channels. Whenever possible, flood waters would be held over for release during the irrigation season. Recreationists would have access to the reservoir, and water supply and sanitary facilities would be provided.

Plans and specifications for the Buchanan Dam and Reservoir are now (1965) being prepared by the Sacramento

District Office of the Corps of Engineers. Construction may commence, contingent upon congressional appropriations, in 1968 and be completed in 1970.

Windy Gap Reservoir

This project was first proposed as a major unit of the ultimate State Water Plan in Bulletin No. 29, "San Joaquin River Basin", a 1931 publication of the Division of Water Resources, Department of Public Works, State of California. At that time the State considered the Hidden site as an alternative and selected the Windy Gap site because storage was less costly. The Oakhurst-Soquel Project is proposed in this report rather than the Windy Gap alternative because it would be a more economical development for the upper Madera area. The Hidden site would control the runoff of practically the entire drainage basin of the Fresno River above the valley floor.

Although not finalized, preliminary studies were made of a possible future Windy Gap Project. The proposed Hidden Reservoir will develop the Fresno River to a high degree insofar as lower Madera County is concerned, and the development of the Windy Gap site should be justified mostly by benefits provided to upper Madera County. The Oakhurst-Soquel Project is proposed in this report rather than the Windy Gap alternative because it would more economically provide greater recreation and domestic water supply benefits for the upper Madera area. The Windy Gap site, however, is the least costly site for storage remaining on the Fresno River and should be reevaluated subsequent to the development of the Hidden site.

Miami Creek Reservoir

This reservoir as proposed in Bulletin No. 3 was considered a possible source of supply for the Oakhurst-Ahwahnee area; however, a more detailed investigation indicates that the Oakhurst-Ahwahnee area can be served more economically from the proposed Oakhurst-Soquel Project. Furthermore, a reservoir at the Miami Creek site would have limited recreation potential because nearly all suitable camping sites would be inundated.

Lewis Fork Reservoir

A considerable number of homes have been constructed within the Lewis Fork Reservoir site since the California Water Plan was formulated. The increased cost of land acquisition at this location would indicate an alternative development.

Nelder Creek Reservoir

Excessive costs of land due to subdivision developments in the reservoir area in recent years have made this proposal infeasible.

Mammoth Pool Reservoir and Powerplant

This project was developed by the Southern California Edison Company subsequent to the publication of the California Water Plan. The project includes an earthen dam on the San Joaquin River, 411 feet in height, which contains 5,355,000 cubic yards of material, and impounds 123,000 acre-feet with a maximum water surface area of 1,100 acres. A tunnel 7.5 miles long along the west side of the San Joaquin River conveys water from the reservoir to a 129,400-kilowatt powerplant at a point on the river about one mile upstream from the confluence of the river with Big Creek. Mammoth Pool Reservoir is used by many recreationists at the present time.

The potential Chiquito, Miller Crossing, and Forks Reservoir Projects were reappraised. This reappraisal resulted in the modified proposals for development which comprise the Upper San Joaquin River Project described in this chapter.

Oakhurst-Soquel Project

The proposed Oakhurst-Soquel Project would provide urban and domestic water supplies for the Oakhurst, Ahwahnee, Coarsegold, North Fork, and South Fork areas, and recreation and fisheries enhancement for the general public in the proposed Soquel Reservoir area and along North Fork Willow Creek, Nelder Creek, and the Upper Fresno River.

The proposed project would include an earthfill dam on North Fork Willow Creek near Soquel Meadow which would create an 8,000-acre-foot reservoir. Project water would be released into the North Fork of Willow Creek and/or into Nelder Creek. A diversion dam on the North Fork of Willow Creek about a mile upstream from Bass Lake would divert project water into a pipeline which would be constructed around the north and west sides of Bass Lake, around the upper portion of the China Creek drainage basin, and along State Highway 41 as far as Coarsegold. A diversion dam on Nelder Creek, and another on Lewis Fork of Fresno River, would divert project water and local runoff into a pipeline for conveyance to Oakhurst and Ahwahnee. This conduit would be aligned along the west side of State Highway 41 and the north side of State Highway 49. Another pipeline would be constructed from Manzanita Lake, a forebay reservoir of the Pacific Gas and Electric Company located about three miles south of Bass Lake, to the communities of North Fork and South Fork. The locations of these features of the proposed project are shown on Plate 17.

Releases of water from Soquel Reservoir during the summer and fall months would enhance the existing fisheries on the North Fork of Willow Creek between the proposed Soquel Dam and Bass Lake. The fishery on Nelder Creek and the Fresno River would likewise be enhanced by the diversion of water from Soquel Reservoir.

The Soquel Reservoir site has an excellent recreation potential because of the natural beauty and pleasant summer climate, easy accessibility, desirable topography, and the public ownership of surrounding lands. Recreation development at Soquel Meadow would relieve the presently overcrowded facilities at Bass Lake.

Consideration of Alternatives

Many alternatives for developing the water resources of the Madera area were considered during the investigation. Among those studied were alternative reservoir sites on the Fresno River at Windy Gap, on the Lewis Fork tributary to the Fresno River above Oakhurst, and on Miami Creek tributary to the Fresno River below Oakhurst. The Soquel site was found superior to all alternative sites for the following reasons:

1. Storage and yield costs are less at the Soquel site than at all alternative sites except Windy Gap. An 8,000 acre-foot reservoir could supply water to meet the requirements of the major areas of urban and rural residential growth in the upper Madera unit to the year 2020.

2. The location and elevation of the Soquel site is such that all the areas of rural and residential growth in the upper Madera unit could be supplied water by gravity service. None of the alternative sites has this advantage.

3. The Soquel site offers greater recreation potential than any of the alternative sites which were studied.

Although storage and yield costs are less at the Windy Gap site, the cost of water supply to the Oakhurst-Ahwahnee area would be greater because the water would have to be pumped. The cost of supplying water to the Coarsegold, Bass Lake, and North Fork-South Fork service areas from Windy Gap would be greater because of the pumping lift and conveyance distance. Other disadvantages to the Windy Gap site are the poor recreation potential and the fact that the reservoir would receive septic tank effluent from urban development in the Oakhurst-Ahwahnee area.

Effect on Present Development

Construction of the Oakhurst-Soquel Project would have considerable impact upon the present development of the upper Madera area. The economic growth of the area would be encouraged as a result of developments associated with both the recreation and conservation functions of the project.

The recreation developments of the proposed Oakhurst-Soquel Project would affect, and be affected by, the existing and proposed recreation facilities of the Bass Lake Ranger District. At the present time facilities at Bass Lake are being overused but could be relieved by construction of facilities at the proposed Soquel Reservoir. A small existing campground, however, would be flooded out by the reservoir.

The Madera Irrigation District would be affected by the conservation aspects of the proposed Oakhurst-Soquel Project. It maintains two diversions which import water from the San Joaquin River drainage basin into the Fresno River drainage basin (Chilkoot and Soquel) and one diversion which imports water from the Merced River drainage basin into the Fresno River drainage basin (Big Creek).

The highest in elevation and the smallest diversion is made from Chilkoot Creek, a tributary of Willow Creek, at an elevation of about 7,100 feet. The water is conveyed by a small, unlined ditch approximately 1,200 feet to a tributary to North Fork Willow Creek.

The second and much larger diversion from the San Joaquin River watershed is made on North Fork Willow Creek at an elevation of about 5,400 feet. It diverts a part of the flows of North Fork Willow Creek, including the diverted flows of Chilkoot Creek. This "Soquel Ditch", consisting of canal and siphon, conveys the water approximately one mile to the headwaters of California Creek, a tributary of Nelder Creek. This diversion is referred to as the "Soquel Diversion" elsewhere in this report (see Plate 17).

A diversion dam on Big Creek, a tributary of the South Fork Merced River, diverts a portion of the flows of Big Creek into Lewis Fork of the Fresno River. This short canal is often referred to as the "Big Creek Ditch" (see Plate 17).

The Oakhurst-Soquel Project as proposed would conserve the water from the present Soquel Diversion for multiple purposes. The project would not regulate water from the Big Creek Diversion during the initial period up to year 1990, but it is proposed that at a later date a higher diversion on Big Creek would divert about 26 percent of the present diversion into Soquel Reservoir. The flows of Lewis Fork, including the Big Creek Ditch flow, would supplement releases from proposed Soquel Reservoir for consumptive purposes in the Oakhurst-Ahwahnee area. The proposed project would affect the water supply of the Madera Irrigation District.

The "Statement of Madera Irrigation Water Rights" prepared by the late Harry Barnes in a report to the Board of Directors of the Madera Irrigation District dated November 6, 1962, contained the following:

> "The primary right of Madera Irrigation District to water of the Fresno River (purchased in 1951 from the Madera Canal and Irrigation Company) consists of the first 200 second-feet of the flow of Fresno River at the dam a couple of miles east of Madera, or the entire flow of the river at that point if the discharge is less than 200 second-feet. This includes foreign water introduced into the watershed of the Fresno River from a branch of the Merced River through Big Creek Ditch and from the North Fork of the San Joaquin River through Soquel Ditch. The Soquel right consists of a maximum of 50 second-feet from Soquel Creek October 1 through July 31 annually, and from Big Creek a maximum of 50 second-feet during each month excepting April when it is reduced to 20 second-feet. (The preceding references to 'North Fork of the San Joaquin River' and 'Soquel Creek' should read 'North Fork Willow Creek'.) The use of this 200 second-feet of water at Madera dates back to 1872 and the right was adjudicated by a decision of the State Supreme Court in 1919.
>
> "This right through long and uninterrupted use has become prescriptive against downstream water users -- both riparian and appropriative, which means that it is immune from attack from those sources. Likewise, it is not affected by later filings to appropriate Fresno River water. Insofar as the natural flow of the stream is concerned, the right is subject to encroachment by riparian water use upstream, to the extent of its reasonable use. These riparians, however, can exercise no claims to any of the foreign water brought into the Fresno River watershed by the Soquel and Big Creek ditches ...."

Because the right to the water proposed to be supplied by the Oakhurst-Soquel Project is held by the Madera Irrigation District, an exchange agreement between the project sponsors and the District would be necessary. Project sponsors could negotiate for additional deliveries from the East Side Division of the Central Valley Project to replace supplies to the Madera Irrigation District.

In the early years of project operation, water requirements in the Upper Madera Unit would be small and proposed releases from Soquel Reservoir would make the Fresno River a live stream throughout the year. Requirements would increase gradually to approximately 7,600 acre-feet annually, or about 44 percent of the average amount imported in the year 2020. An estimated 50 percent of the requirements would be consumptively used, and the remainder would return to the Fresno River as effluent seepage. The overall effect of the project would be a small, gradual reduction in the water supply of Madera Irrigation District from the Fresno River to provide supplemental water supplies for upstream areas. From the first, however, significant recreation and fishery enhancement benefits would be realized.

Major Project Features

The proposed Oakhurst-Soquel Project would consist of Soquel Dam and Reservoir, recreation facilities, Oakhurst-Ahwahnee Diversion Dams and Pipeline, Bass Lake-China Creek-Coarsegold Diversion Dam and Pipeline, and North Fork-South Fork Pipeline. Proposed recreation facilities are described in a separate section.

Soquel Dam and Reservoir. The proposed reservoir site is located about six miles north of Bass Lake and about seven miles southeast of the southern (State Highway 41) entrance to Yosemite National Park. Access to the reservoir site is provided by three routes, two from Highway 41 and one from "The Pines" at Bass Lake. The shortest and best route from Madera or Fresno is from Highway 41 at the turnoff to Sky Ranch, about three-quarters of a mile north of Yosemite Forks. From Highway 41 about six miles of well maintained dirt road leads to the site.

The proposed Soquel Dam would be located on North Fork Willow Creek in the southeast corner of Section 16, Township 6 South, Range 22 East, MDB&M. Streambed elevation at the damsite is 5,240 feet. Portions of Sections 9, 10, 15, and 16, Township 6 South, Range 22 East, would be inundated by the reservoir.

Aerial photographs of the site were taken in October of 1961, and topographic maps of the reservoir area were prepared with a scale of one inch equals 300 feet and with a contour interval of 10 feet. Table 28 provides pertinent data on the reservoir site.

The dam would be a modified homogeneous earthfill structure 110 feet in height at the maximum section. Plate 17 presents the plan and cross sections of the proposed dam and a general layout map of the overall project. The crest length of the dam would be 700 feet, the crest width 30 feet, the upstream slope 3:1 and the downstream slope 2:1.

The axis of the dam would be in a moderately steep section of the stream underlain by a narrow belt of black quartz mica schist. This belt of schist, bounded on each side by granitic rock, is several hundred feet wide and trends northwest, nearly parallel to the axis of the dam. The main portion of the dam would be founded on granitic rock with the extreme upstream toe on schist. The quartz mica schist is fine-grained with discernible mica flakes, is schistose (platy), and is moderately fractured near the surface. It is hard and appears massive in the channel section where it is fresh. The schistosity becomes more pronounced upon weathering as shown in the abutments.

The granitic rock is hard and massive where it is unweathered. On the abutments the granitic rock is covered by a variable depth of decomposed granite. The granitic rock is gneissose at the contact with the lineation somewhat parallel with the schist contact.

Stripping would consist mainly of excavation in soil and weathered rock to a depth of about ten feet in the abutments and about five feet to shape bedrock and remove channel deposits in the channel section. A positive cutoff would be extended to bedrock which may be 20 feet normal to the slopes on the abutments. Grouting of the bedrock is expected to be light, ranging from about 0.1 to 2.0 cubic feet per linear foot of hole.

The most suitable spillway would probably be a side channel spillway in the left abutment of the dam. Although no natural reentry can be utilized, spills would be discharged below an eastward turn of the stream. The spillway crest, trough, and chute would be founded on decomposed granite and granitic rock. Lining would likely be required for the entire length of the trough and chute because depth to bedrock is estimated to be about 25 feet.

The spillway would pass the probable maximum flood of 21,500 second-feet with two feet of freeboard. The chute would terminate with a flip bucket designed to traject discharges onto the unweathered granite in the stream channel.

TABLE 28

AREAS AND CAPACITIES OF SOQUEL RESERVOIR

Depth of Water at Dam, in Feet	Water Surface Elevation, in Feet (USGS datum)	Water Surface Area, in Acres	Storage Capacity, in Acre-feet
0	5,240	0	0
10	5,250	8	40
20	5,260	13	140
30	5,270	26	330
40	5,280	42	670
50	5,290	65	1,200
60	5,300	89	1,980
70	5,310	122	3,030
80	5,320	164	4,460
90	5,330	215	6,360
100	5,340	271	8,790
110	5,360	337	11,820

The proposed outlet works are reinforced concrete cut-and-cover type having a 44-inch diameter. A design discharge of 135 second-feet would be regulated by a gate valve located in a valve chamber with access from a well located near the axis of the dam.

On the basis of the preliminary reconnaissance survey, both impervious earthfill and pervious rockfill appear to be available nearby in sufficient quantities for the proposed structure. The impervious material would be in the form of decomposed granite and fluvial and lacustrine meadowland deposits. Minor amounts of fluvial and lacustrine deposits occur in the meadowlands toward the head of the proposed reservoir. Pervious material for riprap and filter drain would be in the form of unweathered granitic rock.

The reservoir area is formed by relatively subdued, branching stream topography underlain almost entirely by granitic rock. No reservoir leakage is expected.

Oakhurst-Ahwahnee Diversion Dams and Pipeline. This feature of the proposed Oakhurst-Soquel Project would consist of a diversion dam on Nelder Creek, a pipeline to Lewis Fork of the Fresno River, a diversion dam on Lewis Fork, and a main distribution pipeline. The dam on Lewis Fork of the Fresno River would provide a small amount of regulatory storage, and the pipeline leading from the diversion dam would convey water to the Oakhurst-Ahwahnee areas.

The proposed Lewis Fork Diversion Dam and Nelder Creek Diversion Dam would be located about 2.5 miles north of Oakhurst in Section 36, Township 6 South, Range 21 East, MDB&M. Streambed elevation at the proposed diversion dams would be about 3,000 feet, USGS datum. The proposed concrete gravity dams would be about 15 feet high. An 18-inch pipeline, one-half mile long, would convey Soquel Reservoir releases from Nelder Creek to Lewis Fork at the dams. A slide gate would permit regulation of diversions into an intake structure and thence into a pipeline having a total length of about eight miles. The first three miles to the approximate vicinity of the intersection of Highways 41 and 49 just south of Oakhurst would be an 18-inch pipeline, the next three miles to the general vicinity of Miami Creek would be 14-inch, and the remaining two miles to Ahwahnee would be 12-inch. It appears that no unusual problems would be encountered in the construction of this project feature.

Releases from Soquel Reservoir in excess of the amounts conveyed in the Oakhurst-Ahwahnee pipeline would spill over Nelder Creek Diversion Dam and flow down Nelder Creek.

Bass Lake-China Creek-Coarsegold Diversion Dam and Pipeline. The proposed North Fork Willow Creek Diversion Dam would be located near the center of Section 9, Township 7 South, Range 22 East, MDB&M about one-half mile upstream from Bass Lake. Streambed elevation would be about 3,760 feet. A 10.7-mile pipeline would convey water from the dam along the north and west sides of Bass Lake, thence along the headwaters of China Creek in a generally southwesterly direction to Coarsegold. The first 3.8 miles to the headwaters of China Creek would be a pipeline 14 inches in diameter, and the remaining 6.9 miles would be a 10-inch pipeline.

North Fork-South Fork Pipeline. The proposed North Fork-South Fork pipeline would extend from Manzanita Lake 1.2 miles to the vicinity of the communities of North Fork and South Fork. The pipeline would be 12 inches in diameter.

The general features of the proposed Oakhurst-Soquel Project are shown in Table 29.

TABLE 29

GENERAL FEATURES OF
THE PROPOSED OAKHURST-SOQUEL PROJECT

Item	Description
Soquel Dam	
Type	Modified homogeneous earthfill
Elevation of streambed, in feet	5,240
Crest elevation, in feet	5,350
Crest height above streambed, in feet	110
Crest length, in feet	700
Crest width, in feet	30
Slopes: Upstream face	3:1
Downstream face	2:1
Volume of fill, in cubic yards	425,000
Soquel Spillway	
Type	Side channel
Crest elevation, in feet	5,337
Crest length, in feet	150
Freeboard above crest, in feet	13
Probable maximum flood peak outflow, in second feet	21,500
Soquel Reservoir	
Storage capacity at minimum pool, in acre-feet	3,000
Storage capacity at normal pool, in acre-feet	8,000
Surface area at minimum pool, in acres	122
Surface area at normal pool, in acres	256
Water surface elevation at minimum pool, in feet	5,310
Water surface elevation at normal pool, in feet	5,337
Drainage area, in square miles	16.3
Oakhurst-Ahwahnee Diversion Dams1/ and Pipeline	
Type of dam	Concrete gravity
Type of spillway	overflow
Type of outlet works:	
Stream outlet	36-inch slide gate
Conduit intake	18-inch slide gate
Lengths, diameters, and capacities of section of pipeline:	
Nelder Creek to Lewis Fork	½ mile, 18-inch, and 13.5 second-feet
Diversion to Oakhurst	3 miles, 18-inch, and 13.5 second-feet
Oakhurst to Miami Creek	3 miles, 14-inch, and 6.7 second-feet
Miami Creek to Ahwahnee	2 miles, 12-inch, and 4.0 second-feet

1/ Nelder Creek and Lewis Fork Diversion Dams would be similar.

TABLE 29 (Continued)

GENERAL FEATURES OF THE
THE PROPOSED OAKHURST-SOQUEL PROJECT

Item	Description
Bass Lake-China Creek-Coarsegold Diversion Dam and Pipeline	
Type of dam	Concrete gravity
Type of spillway	Overflow
Type of outlet works:	
Stream outlet	36-inch slide gate
Conduit intake	14-inch slide gate
Lengths, diameters, and capacities of sections of pipeline:	
Diversion to China Creek	3.8 miles, 14-inch, and 7.0 second-feet
China Creek to Coarsegold	6.9 miles, 10-inch, and 2.8 second-feet
North Fork-South Fork Pipeline	
Type of intake	12-inch slide gate at Manzanita Lake
Length, diameter, and capacity of pipeline:	1.2 miles, 12-inch, and 2.5 second-feet

Proposed Operation

The Soquel Reservoir site and watershed is located in a moderately heavily timbered region of the Sierra National Forest. The 16.3 square miles of watershed range from 5,340 to 9,100 feet in elevation. Precipitation on the watershed averages about 48.3 inches and the mean annual runoff is about 17,300 acre-feet. Most of the runoff originates as snowmelt from April through July. The estimated probable maximum flood of 21,500 second-feet would have a duration of 87 hours and a volume of 47,900 acre-feet. Flood routings through the proposed 8,000-acre-foot reservoir indicated that the reduction from inflow to outflow would be very small, so the spillway was designed to pass 21,500 second-feet.

The project would conserve and regulate water from the "Soquel Diversion" for service to the Oakhurst, Ahwahnee, Bass Lake, China Creek, Coarsegold, North Fork, South Fork, and other nearby areas. The Oakhurst-Ahwahnee area would be supplied by pipeline from diversions near Yosemite Forks (Lewis Fork and Nelder Creek Diversions). These small dams and reservoirs would have some regulatory effect and would facilitate the diversion of natural flows of Lewis Fork and

Nelder Creek, diversions from Big Creek, and also supplemental releases from Soquel Reservoir. Soquel Reservoir would furnish the entire supply for the Bass Lake, China Creek, Coarsegold, North Fork, and South Fork areas.

The Soquel and Big Creek diversions have operated for more than 50 years, but they have been measured for only a short time. The recent records of the Soquel Diversion, as obtained by the Madera Irrigation District and the Big Creek Diversion records of the Department of Water Resources, indicate fairly accurately the amount of water that would be available to the proposed project under existing water rights and diversion practices.

The operation of Soquel Reservoir has been based on the premise that "Soquel Diversion" would constitute the only inflow. This assumption was made to illustrate that all project water could be obtained from this source. In practice, the natural flow of North Fork Willow Creek would probably be regulated to some extent in conjunction with project operations. Such an operation should be conducted if feasibility studies of this site are made later.

Monthly operation studies of the proposed Soquel Reservoir were based on a repetition of hydrological conditions from October 1913 through September 1963 and on estimated future water demand conditions. These operation studies are presented in Appendix A. An annual summary of this operation study with water demands estimated to occur about 1990 is shown in Table A-1. The monthly operation study during the most critically dry condition is shown in Table A-2. The study indicates that the estimated 1990 water demand of 3,345 acre-feet (1,470 acre-feet in the vicinity of Oakhurst and Ahwahnee and 1,875 acre-feet in other project areas) could be met with a maximum drawdown of only 1,675 acre-feet, or about 10 feet, in Soquel Reservoir.

By the year 2020 it is estimated that water requirements in the proposed project service areas will increase to 3,745 acre-feet for the Oakhurst-Ahwahnee area and 3,840 acre-feet for the other service area. By the time these amounts of water are needed an additional supply to the reservoir will also be required. This can be achieved by construction of a small diversion dam on Big Creek near Fresno Dome in Section 34, Township 5 South, Range 22 East, MDB&M, and a short ditch to a tributary of North Fork Willow Creek above Kelty Meadow camp ground. These facilities would divert about 26 percent of the "Big Creek Ditch" diversion into Soquel Reservoir.

Another similar monthly reservoir operation study was made by using the estimated water requirements for the year 2020. An annual summary of the results of the operation study is shown in Table A-3. The critical dry period for the 2020 demand was found to be under water supply conditions which occurred between July 1930 and May 1932. The monthly operation during the most critical dry period is shown in Table A-4 and indicates a maximum drawdown of about 5,000 acre-feet.

Water Conservation Aspects

Population projections indicate the population in the Oakhurst-Soquel Project service areas will increase from an estimated 5,500 in 1970 to an estimated 23,000 in 2020. Water supplies would be furnished to urban consumers in the towns of Oakhurst, Ahwahnee, Coarsegold, North Fork, and South Fork, and to rural domestic homesites located throughout Study Areas 13 through 17 (see Plate 16). About 100 acres of commercial agricultural land in Study Area 13 would also be served.

Current water supplies in the study areas which would be served by the proposed Oakhurst-Soquel Project are derived almost entirely from ground water. A preliminary area-wide geological reconnaissance survey indicates there is sufficient ground water recharge directly from precipitation to meet the estimated future water requirements of the proposed project service areas, but only a small fraction of the ground water supplies could be economically developed. As the service areas experience more urban-type development, ground water in the vicinity of growth will not be sufficient to meet requirements. There also exists the problem of imminent pollution of both ground water and surface water in the areas of concentrated development, as noted in Chapter 2.

The cost of water produced from wells is relatively high in the upper Madera area because of the initial cost of the well and pump and the low yield of water from wells in crystalline rock. It is estimated that water produced from wells in the upper Madera area costs about $200 per acre-foot A safe dependable supply could be obtained from the Oakhurst-Soquel Project for considerably less.

In estimating future water requirements for the project service areas, consideration was given to the likelihood that most of the existing wells would continue in service until failure occurred and that some rural homes would be too remote to be economically served by pipeline.

Project water requirements were based on projected population and on the following estimates and assumptions:

1. One-third of the population would reside in urban areas and two-thirds in rural homesites.

2. Domestic water requirements would be about one-fourth acre-foot per capita annually, or about 220 gallons per day.

3. Rural homesites would on the average have one-eighth of an acre of gardens and home orchards with a water requirement of 3.2 acre-feet per acre, or 0.4 acre-foot per homesite.

Table 30 presents anticipated water requirements by decades from 1970 through 2020 by study areas. Table 31 shows the proposed distribution of year 2020 water requirements by pipelines to the service areas of the proposed project.

Recreation Aspects

The Soquel site is in one of the most beautiful areas of the Sierra Nevada. The hills are heavily forested except for the occasional granite spire which provides an aura of majesty to the landscape. Kellogg oak, red fir, white fir, lodgepole pine, sugar pine, ponderosa pine, and incense cedar adorn the slopes. Some of the valleys contain lush meadows which remain wet and green well into the summer. The year-round streams which bisect the valleys are cool and clear. Trout lurk in the deeper pools, awaiting the angler's fly. Along the banks of the streams a few gnarled cottonwoods add rugged character to the docile beauty of the pine forest.

Mule deer, black bear, coyotes, and an occasional wandering mountain lion are native to this portion of Madera County. The western gray squirrel, brush and jackrabbits, mountain quail, Sierra grouse, and infrequently band-tailed pigeons are also native to the upland region. Some of the smaller furbearing inhabitants are raccoons, skunks, weasels, badgers, foxes, porcupines, and bobcats. A golden or bald eagle may sometimes be seen soaring over the craggy spires of the granite outcroppings.

The climate at Soquel Meadows (elevation 5,300 feet) is much more varied than that of the San Joaquin Valley floor. Recreationists may expect an occasional thunderstorm during the summer months. The area is usually closed by snow from the middle of November until the middle of May. Temperature data are not available for the project area, but experience indicates summer daytime temperatures are usually in the 80's with nighttime temperatures in the 60's. The average annual precipitation is about 45 inches.

During this investigation, estimates have been made of present and future developments under "nonproject" and "project" conditions to estimate "net project" conditions attributable to the proposed Oakhurst-Soquel Project. These estimates give some idea of the recreation potential of the proposed Soquel Reservoir site and how it fits into the overall development of the Bass Lake Ranger District of the Sierra National Forest.

TABLE 30

FUTURE WATER REQUIREMENTS
IN OAKHURST-SOQUEL PROJECT STUDY AREAS
(in Acre-feet)

Study Area	Type of Use	Year 1970	1980	1990	2000	2010	2020
13 1/	Domestic	200	625	1375	2025	2750	3500
	Garden & Home Orchard	85	270	590	860	1170	1470
	Commercial Agriculture	260	260	260	260	260	260
	Total	545	1155	2225	3145	4180	5250
14 2/	Domestic	75	150	300	350	400	450
	Garden & Home Orchard	0	0	0	0	0	0
	Total	75	150	300	350	400	450
15 3/	Domestic	100	175	375	500	625	750
	Garden & Home Orchard	45	75	160	210	270	320
	Total	145	250	535	710	895	1070
17 4/	Domestic	50	90	200	300	425	575
	Garden & Home Orchard	20	35	85	130	180	240
	Total	70	125	285	430	605	815
Total	Domestic	425	1040	2250	3175	4200	5275
	Garden & Home Orchard	150	380	835	1200	1620	2050
	Commercial Agriculture	260	260	260	260	260	260
	Total	835	1680	3345	4635	6080	7585

1/ About 70 percent of Study Area 13 would be served by Oakhurst-Ahwahnee pipeline. The remaining 30 percent (China Creek) would be served by the Bass Lake-China Creek-Coarsegold pipeline.

2/ Study Area 14 (Bass Lake) would be served by Bass Lake-China Creek-Coarsegold pipeline.

3/ Study Area 15 would be served by North Fork-South Fork pipeline.

4/ Study Area 17 would be served by Bass Lake-China Creek-Coarsegold pipeline.

TABLE 31

PROPOSED DISTRIBUTION OF
OAKHURST-SOQUEL PROJECT WATER SUPPLIES FOR THE YEAR 2020
(in Acre-feet)

Service Area	Amount	
Oakhurst-Ahwahnee:		
Oakhurst area	1,645	
Oakhurst-Miami Creek area	1,050	
Ahwahnee area	1,050	
		3,745
Bass Lake-China Creek-Coarsegold:		
Bass Lake area	450	
China Creek area	1,505	
Coarsegold area	815	
		2,770
North Fork-South Fork		1,070
Total		7,585

Present Recreation Use in the Bass Lake Ranger District. The U. S. Forest Service lands in the area are managed for timber production, watershed protection, grazing, wildlife, and recreation. Recreation uses include camping, hunting, riding, hiking, fishing, and many secondary outdoor recreation pursuits. There is a small campground within the proposed reservoir area that would be flooded out by the proposed reservoir, but the extent of facilities thus lost is insignificant.

Bass Lake is the main attraction of the Bass Lake Ranger District. This lake, also called Crane Valley Storage Reservoir, is owned by the Pacific Gas and Electric Company. The lake has 1,165 surface acres at normal pool. The northeastern shoreline of the lake is extensively developed as far south as Pines Creek with summer homes and commercial establishments. The southeastern shoreline is largely undeveloped south of Pines Creek. Approximately two-thirds of the western shoreline is used by the U. S. Forest Service for campgrounds and day-use areas.

There is a paved road into and through the Bass Lake recreation area. Eleven areas are available for recreation along the Bass Lake perimeter. Seven of these are family-type campgrounds, three are family-type picnic areas, and one is a group picnic area. Facilities available in Bass Lake recreation area and other areas of the Bass Lake Ranger District are shown in Table 32.

TABLE 32

RECREATION FACILITIES AVAILABLE IN 1963
IN BASS LAKE RANGER DISTRICT

(Does Not Include Commercial Developments)

Designation of Area	Campgrounds and Picnic Areas	Camp Units	Picnic Units	Unimproved Areas	Group Units
Bass Lake Recreation Area	11	312	40		2
Miami-Fish Camp-Mt. Raymond-and-Fresno Dome Recreation Area	8	84			
Iron Creek-Grizzly Creek Recreation Area	4	1		3	
Nelder Grove-Soquel Recreation Area	4	30			
Chilkoot (Central Camp Recreation Area)	3	12			
Pack Camps	6	0		3	
Totals	36	439	40	6	2

The recreation facilities available to the public in 1963 at Bass Lake comprised 68 percent of the total facilities available within the district. The visitor-day attendance for 1963 at Bass Lake was 83 percent of the total use of the district (see Table 33).

U. S. Forest Service personnel estimate that the capacity of its camping facilities at Bass Lake should be set at a maximum of about 1,875 visitors per day. In 1963

TABLE 33

COMPARISON OF FACILITIES AND RECREATION USE
IN BASS LAKE RECREATION AREA
AND BASS LAKE RANGER DISTRICT IN 1963

Designation of Area	Acres	Facilities Number	Facilities Percent	Visitor-Days Number	Visitor-Days Percent
Bass Lake Recreation Area	4,077	354	68	422,754	83
Bass Lake Ranger District	76,100	523	100	511,700	100

the facilities had over 2,320 visitors per day, a 24-percent overuse. The facilities attract 4,000 to 5,000 campers per day during the summer holidays and weekends. The day-use areas at Bass Lake can accommodate 720 visitors per day assuming a maximum turnover without damage to the ecological resources of the site. The Forest Service estimated an annual average use at Bass Lake of approximately 1,900 visitors per day -- 2.5 times the optimum capacity. The heavy overuse of the Forest Service areas causes "human erosion"1/ and detracts from the esthetic values of the recreation experience.

The day-use visitors to the Bass Lake recreation area are preponderantly from the Fresno-Madera population centers. The California Public Outdoor Recreation Plan -- Part I, states: "The average one-way distance for one-day round trips, by automobile -- for outdoor recreation -- is 35 miles." Madera and Fresno are 53 and 58 miles, respectively, from Bass Lake. These distances are near the maximum range of one-day round trips, considering also recreation time.

An analysis of 888 visitor registration cards at the Bass Lake recreation area ranger station indicated that 59 percent of the overnight visitors were from south of the Tehachapi Mountains (see Table 34).

Personnel of the Bass Lake Ranger District indicated from their experience that the Bass Lake recreation area is used quite heavily by Southern Californians. Carrying this analysis one step further we can assume that 73 percent of the campers have driven over 200 miles from their point of origin to use the recreation facilities at Bass Lake.

1/ The deterioration of an area due to littering or mutilating the landscape, soil compaction, undue vegetative removal, etc.

TABLE 34

ANALYSIS OF VISITOR REGISTRATION CARDS AT THE BASS LAKE RANGER STATION

(Months of June and July 1964, Camping Only)

Area of Origin	Number of visitors	Percent of Total
Bay Area	138	2.6
San Joaquin Valley	1,450	27.1
Southern Area	3,110	58.5
Central Coast	516	9.8
Northern Area	24	.4
Out of State	84	1.6
Totals	5,322	100.0

The remainder of the Bass Lake Ranger District is not as accessible as Bass Lake. The roads are unpaved and much of the district is closed by snow in the winter. Fishermen, hunters, hikers, and riders make up a large percentage of those who use the outlying parts.

Recreation Use in Bass Lake Ranger District Without Soquel Reservoir. The Sierra National Forest staff has projected recreation development and visitor use for the Bass Lake Ranger District for the years 1976 and 2000, based on past attendance and predicted future recreation demands. The 1976 projection for the Bass Lake Ranger District is 2,000,000 visitor-days. The 1960-63 Bass Lake Ranger District Annual Statistical Reports indicate an average of 60 percent of the recreation use of the district was in camping and picnicking at Forest Service facilities. Assuming that this percentage would hold true for the year 1976, there would be a demand of 1,200,000 visitor-days for camping and picnicking facilities.

Some of the recreation planning standards observed by the Forest Service are as follows:

1. Capacity use per year: 50-day season (except Bass Lake Recreation Area which would be closer to a 100-day season).

2. Campsites: Three units per acre at five persons per unit per day.

3. Group camping: Fifteen persons per acre per day.

4. Day use: Three units per acre for five persons per unit per day with a turnover rate of two.

Table 35 presents information on projected recreation development in the Bass Lake Ranger District. Assuming full development of the acreage indicated in Table 35, an annual use of 1,125,000 visitor-days for the year 1976 is predicted. The demand for that year would exceed the capacity of use by 10.5 percent. The year 2000 would have an annual use of 1,372,000 visitor-days.

TABLE 35

PROJECTED ACREAGE DEVELOPMENT BY SIERRA NATIONAL FOREST FOR BASS LAKE RANGER DISTRICT

Type of Development	Projected Year		
	1963	1976	2000
Camping	131	882	1034
Day Use	25	156	242
Public Group Camping	0	100	100

The Bass Lake recreation area has reached maximum development and it is assumed that over-capacity use would continue indefinitely. Table 36 indicates the projected visitor-day use over a 50-year period (1970-2020) without the Soquel Reservoir.

Without development of the proposed Soquel Reservoir there would be by the year 1970 an estimated 15,000 visitor-days of annual use at the existing Soquel Campground. This amount of use has been considered as the "safe capacity" of the site under nonproject conditions.

Recreation Use In Bass Lake Ranger District With Soquel Reservoir. The California Public Outdoor Recreation Plan -- Part II, states: "In California, recreation is characteristically water-oriented: 60 percent of all recreation tallied in this study (except travel) was water-oriented". This would include boating, swimming, fishing, and other minor

TABLE 36

ANTICIPATED RECREATION USE IN BASS LAKE RANGER DISTRICT WITHOUT SOQUEL RESERVOIR

(Family Camping, Picnicking, and Public Group Camping, in Visitor-days per Annum)

Year	Bass Lake*	Other**	Total
1970	390,000	560,000	950,000
1980	390,000	835,000	1,225,000
1990	390,000	950,000	1,340,000
2000	390,000	982,000	1,372,000
2010	390,000	1,005,000	1,395,000
2020	390,000	1,015,000	1,405,000

*Use is above "safe capacity" of approximately 322,000. Sa capacity is the capability of an area to maintain its natu values without area deterioration while serving anticipate visitor use.

**This includes 15,000 visitor-days of overnight use at existing camp grounds.

water sports. Assuming the trend to water-associated recrea- tion remains at 60 percent, there would be a minimum demand of 570,000 visitor-days per year by 1970 for water-associate recreation resources in the Bass Lake Ranger District.

Fishing is considered poor to fair at Bass Lake; therefore, most of the fishing occurs in other portions of the ranger district. Fishing accounted for five and one-hal percent of all outdoor recreation in Madera County in 1958. Assuming this percentage to hold true for the investigation area, fishing as a water-oriented recreation pursuit would account for 52,000 visitor-days in 1970.

The present use of the Bass Lake recreation area is approximately for 390,000 visitor-days per year. The "safe" use of the area is estimated at a capacity of 322,000 visitor-days per year.

The minimum demand for water-associated recreation in the Bass Lake Ranger District of 570,000 visitor-days per year by 1970 less the "safe" visitor-days capacity at the Bass Lake recreation area and the annual fishing visitor- days in the ranger district leaves an unsatisfied demand for water-associated recreation of 196,000 visitor-days per year

1970. The Soquel Reservoir Project recreation potential would meet this demand.

Experience has shown that the creation of a new recreation resource tends to create an additional demand for it. If the demand for water associated recreation increases proportionate to the expected population increase, the demand will exceed the capacity of both Soquel and Bass Lake by the year 2000. Table 37 shows the anticipated recreation use of the Bass Lake Ranger District with the development of Soquel Reservoir.

TABLE 37

ANTICIPATED RECREATION USE IN BASS LAKE RANGER DISTRICT WITH SOQUEL RESERVOIR

(Family Camping, Picnicking, and Public Group Camping, in Visitor-days per Annum)

Year	Bass Lake*	Soquel Day Use	Soquel Overnight Use	Other**	Total
1970	322,000	23,000	167,000	535,000	1,047,000
1980	322,000	44,000	246,000	888,000	1,500,000
1990	322,000	64,000	336,000	1,003,000	1,725,000
2000	322,000	69,000	421,000	1,035,000	1,847,000
2010	322,000	69,000	421,000	1,058,000	1,870,000
2020	322,000	69,000	421,000	1,073,000	1,885,000

* Based on "safe capacity".
** The project would eliminate the existing Soquel campground, which would have an estimated annual use of 15,000 visitor-days per year by 1970. The visitor-days entries in the column titled "other" have been correspondingly reduced by 15,000 visitor-days which are included in gross use at Soquel.

Proposed Recreation Development. Large portions of land in and around the Soquel Meadow site could readily be developed for recreation use. There are over 400 acres of land with slopes of 10 percent or less. Lands along the north side and the east end of the reservoir are for the most part well suited for recreation development. A portion of the southern perimeter of the reservoir would be too steep for recreation use.

Provision should be made for the acquisition of a strip of land 300 feet wide measured horizontally from the maximum pool shoreline. This recreation land surrounding the reservoir would be developed for general project purposes. Approximately 94 acres of this strip would be used for recreation. An additional 772 acres should be developed to provide adequate recreation facilities.

Initially, recreation development should commence on the north shore of the reservoir. A day-use area of 3 acres and a family camping area of 45 acres would be needed. Initial development on the south shore should start with a 20-acre parcel for group camping. Table 38 gives the projected future recreation development by decades. Plate 18 presents a land-use plan for the proposed Soquel recreation development.

TABLE 38

RECREATION DEVELOPMENT BY DECADES
AT SOQUEL RESERVOIR

Year	Family Camp Units	Family Picnic Units	Group Camp Units	Beach Areas	Boat Ramps	Parking Areas
1970	425	30	2	400'	1-2 lane	1½ acres
1980	240	35	2	500'	-	1 acre
1990	275	35	2	400'	-	½ acre
2000	200	-	-	300'	-	1 acre
2010						
Totals	1140	100	6	1600'	1-2 lane	4 acres

Fish and Wildlife Aspects

The fisheries of Nelder Creek and North Fork Willow Creek could be enhanced because low flows normally occur during the late summer and early fall which could be augmented by releases from the proposed Soquel Reservoir. The climate of the area is such that streams would be open and accessible for trout fishing all season long. Because of the easy access and a predicted use which would overtax the natural fishery, a catchable trout program would probably be desirable.

The natural fishery at the proposed Soquel Reservoir is predicted to be average, and catchable trout probably should be planted as in the cases of Nelder Creek and North Fork Willow Creek.

The Soquel Reservoir site is on the migration route of the Oakhurst deer herd. Since no ditches, conduits, or any barriers are proposed which would interfere with the passage of the deer, no detriment to deer and other wildlife is foreseen. Conversely, the reservoir would not enhance wildlife in the area.

Project Benefits

Potential benefits which would accrue from the proposed Oakhurst-Soquel Project have been estimated for the conservation and recreation functions. However, it was not possible to evaluate either fishery or wildlife benefits.

Water Conservation Benefits. Urban water prices have been analyzed for foothill portions of several counties of the Sierras. These studies indicate that a reasonable value for potable water for domestic use is $115 an acre-foot. Rural homesites in the project service area are expected to average about three-quarters of an acre. In addition to the domestic water requirements, garden and home orchard irrigation is planned for about one-eighth acre per average homesite. Most of these homes would be built by retired people and those employed locally. Previous analyses made for similar areas have resulted in an estimated benefit of about $50 per acre-foot for water for garden and home orchard use.1/

A value of $90 per acre is used herein in estimating benefits to commercial agriculture. The $90 figure is an estimate derived from previous investigations rather than a calculated amount for this particular area; however, since the estimated acreage used for agriculture is only 100 acres, any error in the unit value of $90 would not significantly affect the benefits of the project.

The present worth of conservation benefits over the 50-year period of analysis totals $6,136,000. This is based on the above unit values for domestic, garden and home orchard, and commercial agriculture (Table 39).

1/ Bulletin No. 145, "Feasibility Study: Agua Fria Investigation", Department of Water Resources, 1964, P. 74.

TABLE 39

DOMESTIC, GARDEN AND HOME ORCHARD, AND COMMERCIAL AGRICULTURAL BENEFITS OF THE OAKHURST-SOQUEL PROJECT

Decade	Project Water Delivery, Mid-point Year, in Acre-feet			Present Worth* of Project Benefits by Decade			
	Domestic	Garden and Home Orchard	Commercial Agriculture	Domestic (Based on $115 per Acre-foot)	Garden and Home Orchard (Based on $50 per Acre-foot)	Commercial Agriculture (Based on $90 per Acre-foot)	Total
1970-1980	730	265	260	$ 681,000	$105,000	$186,000	$ 972,000
1980-1990	1,645	605	260	1,035,000	164,000	126,000	1,325,000
1990-2000	2,710	1,020	260	1,155,000	189,000	85,000	1,429,000
2000-2010	3,685	1,410	260	1,060,000	177,000	58,000	1,295,000
2010-2020	4,735	1,835	260	921,000	155,000	39,000	1,115,000
			Totals	$4,852,000	$790,000	$494,000	$6,136,000

*Present worth is based on values at mid-point year of each decade.

Recreation Benefits. The values of $1.00 and $1.50 per visitor-day of use were estimated for day use (picnicking and sight-seeing) and overnight use (camping), respectively. No benefit is claimed herein for the 15,000 visitor-day overnight use predicted for the Soquel Campground without the Soquel Reservoir.

The present worth of the net recreation benefits over the 50-year period of analysis at the Oakhurst-Soquel Project totals $10,273,000 (Table 40).

Project Costs

The estimated costs of the proposed Oakhurst-Soquel Project presented in this section would be adequate to provide for the conservation and recreation purposes of the project. Further studies would be required to determine whether additional costs would be justified for fish enhancement, and the manner in which project costs should be assigned to the fishery and other possible purposes of the project.

Joint Costs. The construction of the proposed Soquel Dam and Reservoir would be necessary to accomplish any of the purposes of the proposed project. The cost of this feature of the Oakhurst-Soquel Project would therefore be borne jointly by all project purposes. Table 41 presents the estimated capital cost of Soquel Dam and Reservoir.

The estimated annual cost for operation, maintenance, and general expense of the dam and reservoir is $8,300. On a present worth basis this would be $177,000 over the 50-year period of analysis. The joint costs on a present worth basis total $1,550,000.

Water Conservation Costs. The specific conservation costs include necessary facilities for diverting and distributing water to the project service areas, and the cost of acquiring a substitute water supply for the Madera Irrigation District. The capital costs of the project distribution system are shown in Table 42. The cost of purchasing substitute water for the Madera Irrigation District is based on preliminary estimates of the cost of East Side Division, Central Valley Project water delivered in the Madera Irrigation District. The present worth of substitute water for the Madera Irrigation District was estimated to be $445,000 over the 50-year period of analysis.

TABLE 40

RECREATION BENEFITS OF THE SOQUEL RESERVOIR

Decade	Day Use			Overnight Use			Present Worth* of Total Recreation Benefits By Decade
	Annual Visitor-days, Mid-point Year	Annual Value Mid-point Year	Present Worth by Decade*	Annual Visitor-days, Mid-point Year	Annual Value Mid-point Year	Present Worth by Decade*	
1970-1980	33,500	$33,500	$ 272,000	191,000	$287,000	$2,328,000	$ 2,600,000
1980-1990	54,000	54,000	295,000	276,000	414,000	2,269,000	2,564,000
1990-2000	67,500	67,500	250,000	363,000	545,000	2,017,000	2,267,000
2000-2010	69,000	69,000	173,000	406,000	609,000	1,523,000	1,696,000
2010-2020	69,000	69,000	117,000	406,000	609,000	1,029,000	1,146,000
Totals			$1,107,000			$9,166,000	$10,273,000

*Present worth is based on values at mid-point year of each decade.

TABLE 41

ESTIMATED CAPITAL COSTS OF SOQUEL DAM AND RESERVOIR

(Based on Prices Prevailing in 1965)

Item	Capital Costs
Dam	$ 510,000
Spillway	307,000
Willow Creek outlet works	53,000
California Creek outlet works	83,000
Reservoir--clearing, grubbing & road relocation	45,000
Subtotal	$ 998,000
Contingencies at 15%	150,000
Subtotal	$1,148,000
Engineering and administration at 15%	172,000
Subtotal	$1,320,000
Interest during construction (2 years at 4%)	53,000
Total first cost of dam and reservoir	$1,373,000

The annual cost of operation, maintenance, and general expense of the distribution system would probably be slightly over one percent of the first cost or about $9,000. The present worth of these annual expenditures would be about $190,000. The separable conservation costs on a present worth basis would total $1,521,000.

Recreation Costs. The estimated capital costs of providing specific recreation facilities over the 50-year analysis period are shown by decades in Table 43. The initial costs include the purchase of private land required for the total recreation development.

The recreation demand indicates the need for development of facilities to be completed during the decade 1990-2000. The costs of family camp units and family picnic units include a pro rata share for sanitary facilities, water systems, interior roads and parking, campsite development,

TABLE 42

ESTIMATED CAPITAL COST OF OAKHURST-SOQUEL
PROJECT DISTRIBUTION SYSTEM
(Based on Prices Prevailing in 1965)

Item	Capital Costs	
1. Oakhurst-Ahwahnee Diversion and Pipeline:		
(a) Diversion dams	$ 40,000	
(b) Pipeline	298,000	
(c) Pipeline appurtenances	6,000	
		$344,000
2. Bass Lake-China Creek-Coarsegold Diversion and Pipeline:		
(a) Diversion dam	$ 20,000	
(b) Pipeline	260,000	
(c) Pipeline appurtenances	4,000	
		$284,000
3. North Fork-South Fork Pipeline:		
(a) Manzanita Lake Diversion	$ 10,000	
(b) Pipeline	30,000	
(c) Pipeline appurtenances	2,000	
		$ 42,000
Subtotal		$670,000
Contingencies @ 15%		100,000
Subtotal		$770,000
Engineering and Administration @ 15%		116,000
Total first cost of project distribution system		$886,000

barriers, signs and a kiosk. The group camp unit cost is based on a unit consisting of 16 tent sites, 7 stoves, 1 barbecue pit, 8 tables, 1 campfire circle, and a pro rata share of the items mentioned above without picnic or campsite development.

The California Division of Beaches and Parks has found that the annual operation and maintenance costs of

TABLE 43

ESTIMATED CAPITAL COSTS OF RECREATION FACILITIES BY DECADES OF THE OAKHURST-SOQUEL PROJECT

(Based on Prices Prevailing in 1965)

Type of Facility	1970	1970-1980	1980-1990	1990-2000
Family camp units	$1,275,000	$720,000	$ 825,000	$600,000
Family picnic units	81,000	94,000	94,000	0
Group camp units	100,000	100,000	100,000	0
Ramp	8,000	0	0	0
Beach	2,000	3,000	3,000	2,000
Parking	11,000	7,000	4,000	7,000
Exterior roads	20,000	20,000	0	0
Water supply	60,000	34,000	0	36,000
Land acquisition	80,000	0	0	0
Totals	$1,637,000	$978,000	$1,026,000	$645,000

recreation facilities at reservoirs amount to about $0.30 per visitor-day. Annual replacement costs for recreation facilities are estimated to be 3.5 percent of the capital investment. Table 44 presents the estimated annual operation, maintenance, and replacement costs during the project repayment period.

The annual operation and maintenance costs are based on the total use at Soquel Reservoir less the estimated 15,000 visitor-days of use of facilities under nonproject conditions in the Soquel site and the 68,000 visitor-days of overuse at Bass Lake. The operation and maintenance cost of these 83,000 visitor-days of annual use was not included because it would have been incurred without the project. The cost of recreation facilities on a present worth basis over the 50-year life of the project totals $7,232,000, including capital costs of $3,231,000 and operation, maintenance, and replacement costs of $4,001,000.

TABLE 44

ESTIMATED ANNUAL OPERATION, MAINTENANCE, AND REPLACEMENT COSTS OF RECREATION FACILITIES AT THE OAKHURST-SOQUEL PROJECT

(Based on Prices Prevailing in 1965)

Year	Operation and Maintenance Costs	Replacement Costs
1970	$ 32,000	$ 54,000
1980	62,000	88,000
1990	95,000	124,000
2000	122,000	147,000
2010	122,000	147,000
2020	122,000	147,000

Comparison of Benefits and Costs

Multiple-purpose water development projects are considered economically justified if the estimated total economic benefits exceed the total economic costs and each project purpose provides benefits at least equal to its separable costs. The present worth of project benefits estimated for the proposed Oakhurst-Soquel Project totals $16,409,000 and the present worth of estimated costs amounts to $10,303,000, giving a benefit-cost ratio of 1.6 to 1.

Upper San Joaquin River Project

The proposed Upper San Joaquin River Project was formulated to initiate future development of water and associated resources of the portion of upper Madera County tributary to Mammoth Pool Reservoir. The project would include the development of three conservation sites (Chiquito, Miller Crossing, and Forks) which were previously proposed in Bulletin No. 3, "The California Water Plan", and one additional site (Jackass Meadow). These proposed reservoirs would be within the picturesque Minarets District of the Sierra National Forest, and would serve to accentuate the attractiveness and utility of the district for recreation. The plan of the proposed project is shown on Plate 19.

The primary purposes of the project would be production of hydroelectric energy, development of recreation facilities, enhancement of fisheries, and development of additional irrigation supplies for the valley floor. A combined gross storage capacity of 221,500 acre-feet would regulate streamflows and provide releases on a power schedule through 10 miles of tunnels, pipelines, and penstocks, and through powerplants having a combined dependable capacity of 191,000 kilowatts.

The recreation potentials of the proposed Jackass Meadow and Chiquito Reservoirs are considered to be good. Jackass Meadow with 2,020 acres of water surface and Chiquito with 540 acres of water surface would be located in moderate to densely timbered regions of the Sierra National Forest, with large adjacent areas available for camping, picnicking, hiking, and other outdoor pursuits. During the summer, the water surfaces of these proposed reservoirs would remain fairly near to the normal pool in all but the driest years.

Benefits accruing from power production are estimated to be $5,890,000 annually. Benefits to be derived from recreation, water conservation and fishery enhancement, although believed to be considerable, were not assigned a monetary value. No determination was made of the detrimental effects of the project on fish and wildlife. Costs of all project features (not including recreation facilities) are estimated to be $4,730,000 annually. This indicates a benefit-cost ratio of about 1.25 to 1 withour considering benefits other than power. The project is economically justified, but further studies would be required to determine the extent to which the various functions should be incorporated.

Location and Accessibility

The Jackass Meadow Reservoir site is on Jackass Creek at a streambed elevation of 6,900 feet, and the Chiquito Reservoir site is on Chiquito Creek at an elevation of 4,800 feet. Both streams are tributary to the San Joaquin River. The Forks Reservoir site is on the San Joaquin River below the confluence of the South and Middle Forks. The Miller Crossing Reservoir site is on the Middle Fork San Joaquin River below the confluence of the Middle and North Forks. The streambed elevations at the Forks and Miller Crossing Reservoir sites are 3,700 and 4,600 feet, respectively.

The best route for access to the proposed project area is Forest Highway 100, also known as the Mammoth Pool Road. Future extension of this road to Devils Postpile National Monument is planned, and the proposed road would be known as the Minarets Summit Highway.

The Jackass Meadow and Chiquito Reservoir sites are accessible from existing roads. Access roads would have to be provided to the Forks and Miller Crossing Reservoir sites, North Fork Diversion Dam site, East and West Fork Granite Creek Diversion Dam sites and the Squaw Dome and Forks Powerplant sites.

Plans for Development

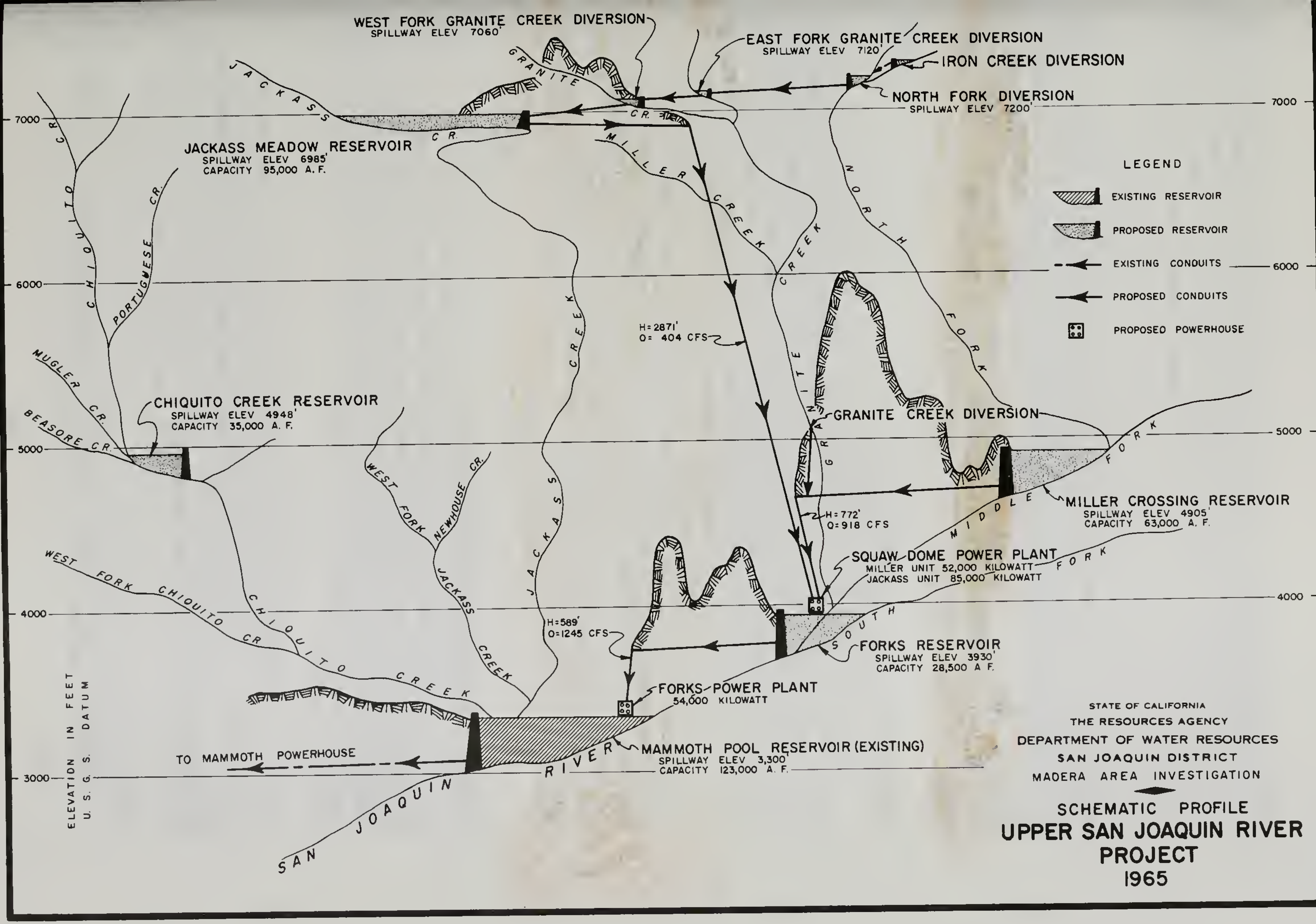
The proposed plan for development is illustrated in Figure 1 and on Plates 19 and 20. The runoff from Iron Creek would be diverted by a small concrete gravity dam and conveyed to a small reservoir formed by a concrete gravity dam on the North Fork San Joaquin River. From this reservoir the combined flows of Iron Creek and the North Fork San Joaquin River would be conveyed by a 10.7-foot-diameter unlined horseshoe tunnel to a point beneath the East Fork of Granite Creek where the flows from the East Fork Granite Creek would be introduced to the tunnel by means of a diversion dam and vertical borehole. From this point the tunnel would be 12.2 feet in diameter, and the combined flows would be conveyed by tunnel and pipeline to a diversion reservoir on the West Fork of Granite Creek. From this reservoir a 14.3-foot-diameter unlined horseshoe tunnel would convey the combined diversions to Jackass Meadow Reservoir.

Jackass Meadow Reservoir would provide 95,000 acre-feet of storage to regulate both the imported flows and the natural flows of Jackass Creek. From Jackass Meadow Reservoir releases would be made on a power demand schedule through tunnel, pipeline, and penstock to a proposed 85,000-kilowatt Jackass Unit of a proposed Squaw Dome Powerplant (see Figure 1). The proposed Jackass unit would be one of the highest head plants (2,871 feet effective head) in the world. Discharge would be into the Middle Fork of the San Joaquin River upstream from the proposed Forks Reservoir. Releases from Jackass Meadow Reservoir would be made at the dam into Jackass Creek for the maintenance, and possible enhancement, of the fishery on Jackass Creek.

A proposed dam at Miller Crossing impounding a maximum of 63,000 acre-feet of water would regulate the flows of the Middle Fork of the San Joaquin River. Releases would be made for the maintenance of the fishery on the Middle Fork San Joaquin River and for power. Releases for the production of power would be through a 15.3-foot-diameter unlined horseshoe tunnel 19,800 feet long, and a penstock to the proposed 52,000-kilowatt Miller Crossing Unit of the Squaw Dome Powerplant. From the powerplant the water would discharge into the Middle Fork of the San Joaquin River.

The power releases from Miller Crossing and Jackass Meadow Reservoirs, and the uncontrolled runoff from the South

FIGURE I



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

SCHEMATIC PROFILE
UPPER SAN JOAQUIN RIVER
PROJECT
1965

Fork of San Joaquin River, would flow into and be regulated by the proposed 28,500-acre-foot Forks Reservoir. Releases from the Forks Reservoir would be made through a 17.2-foot-diameter unlined horseshoe tunnel, 19,800 feet in length, and a penstock to the proposed 54,000-kilowatt Forks Powerplant. From the powerplant the water would flow into Mammoth Pool Reservoir.

Chiquito Reservoir, with a gross capacity of 35,000 acre-feet, would develop 24,000 acre-feet of safe annual yield, which would be released from the dam into Chiquito Creek. The cost of developing power between Chiquito Reservoir and Mammoth Pool Reservoir would probably not be justified. Chiquito Reservoi site has a good recreation and fishery potential, and power benefits from existing powerplants below Mammoth pool would provide benefits in excess of the costs of Chiquito Reservoir.

Consideration of Alternatives

A total of twelve basic plans and several variations of the twelve plans were investigated before adopting the development plan presented herein. An attempt was made to give due consideration to recreation and fish and wildlife benefits and/or detriments. Various proposals were discussed with personnel of the Sierra National Forest (For example, an attempt wasmade to include a smaller reservoir at the Jackass Meadows site because it would probably be less detrimental to wildlife. The magnitude of powe benefits of the large Jackass Meadows Reservoir, however, appeared to outweigh detrimental effects.) Project feasibility studies, including rather extensive recreation and fish and wildlife studies, might requi modifications of the proposed project."

Effects on Existing Development

Existing developments that would be affected by the proposed Upper San Joaquin River Project are the Southern California Edison Company's power development on the San Joaquin River, the Pacific Gas and Electric Company's Kerckhoff Reservoir and Powerplant, and the U. S. Bureau of Reclamation's Millerton Lake.

The Southern California Edison Company has an extensive power development on the San Joaquin River and its tributaries. The development was initiated in 1913[1/] when Big Creek No. 1 and Big Creek No. 2 powerplants were constructed, and since then has been expanded. In 1959[2/] the latest addition, Mammoth Pool Reservoir and Powerplant, was completed. Th

1/ Federal Power Commission, "Hydroelectric Plant Construction Cost and Annual Production Expenses", 1961

2/ Ibid.

system has six storage reservoirs having an aggregate storage of 559,000 acre-feet[3] and seven powerplants having a combined name plate generating capacity of 584,900 kilowatts[4]. Forty-two miles of tunnels convey water from diversion dams and storage reservoirs to the powerplants[5].

The Upper South Fork of the San Joaquin River and Big Creek drainage basins have been extensively developed for power while the main stem above Mammoth Pool Reservoir and the Middle and North Forks remain undeveloped. The Upper San Joaquin River Project as proposed herein would develop these resources of the San Joaquin River above Mammoth Pool Reservoir. Figure 2 is a map showing the existing (1965) development of the San Joaquin River by the Southern California Edison Company, Pacific Gas and Electric Company and the U. S. Bureau of Reclamation. Also shown is the Upper San Joaquin River Project as proposed in this report.

The proposed Upper San Joaquin River Project would have a direct effect on three of Southern California Edison Company's powerplants on the main stem of the San Joaquin River. These are the Mammoth Pool, Big Creek No. 3 and Big Creek No. 4 Powerplants, in order of decreasing elevation. Also directly affected would be Pacific Gas and Electric Company's Kerckhoff Powerplant, the lowermost powerplant on the San Joaquin River.

Mammoth Pool with an active storage of 120,000 acre-feet only partially regulates the estimated 875,000 acre-feet of mean annual inflow. Additional upstream reservoirs would conserve some of the snowmelt runoff which would spill during the spring months of normal and wet years, thereby increasing the energy output of downstream powerplants; furthermore, the additional storage would provide carry-over water to dry years which would increase the dependable capacity of downstream powerplants.

Regulation by the proposed project would also benefit the U. S. Bureau of Reclamation's Millerton Lake operation where releases are made primarily on an irrigation schedule. During wet years, spills would be reduced resulting in an increase of Class 2 water; and during dry years, project releases would provide additional Class 1 water. There would be no increases in project storage during subnormal runoff years to reduce

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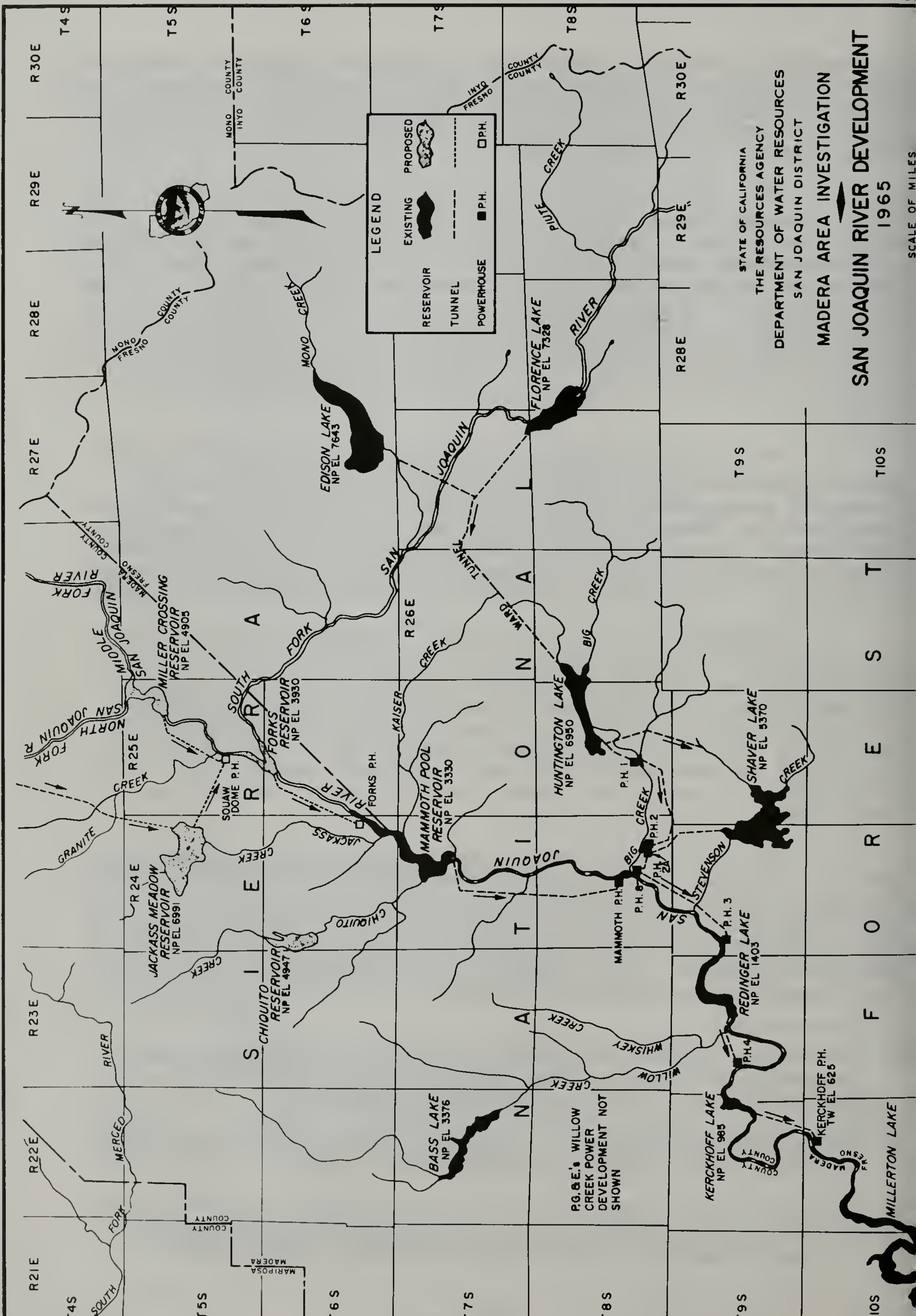
3/ "Operating Contract Relating to Southern California Edison Company's Mammoth Pool and Existing Projects on the San Joaquin River", executed September 23, 1957.

4/ Federal Power Commission, "Hydroelectric Plant Construction Cost and Annual Production Expenses", 1961.

5/ Journal of the Power Division, Proceedings of the American Society of Civil Engineers, Paper 4087, "Unlined Tunnels of the Southern California Edison Co.", October 1964.


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
SAN JOAQUIN RIVER DEVELOPMENT
1965
SCALE OF MILES
LEGEND
EXISTING
PROPOSED
RESERVOIR
TUNNEL
POWERHOUSE
P.H.
SIERRA NATIONAL FOREST
EDISON LAKE
NP EL 7643
FLORENCE LAKE
NP EL 7328
HUNTINGTON LAKE
NP EL 6950
SHAVER LAKE
NP EL 5370
MILLER CROSSING RESERVOIR
NP EL 4905
FORKS RESERVOIR
NP EL 3930
MAMMOTH POOL RESERVOIR
NP EL 3330
JACKASS MEADOW RESERVOIR
NP EL 6991
CHIQUITO RESERVOIR
NP EL 4947
REDINGER LAKE
NP EL 1403
KERCKHOFF LAKE
NP EL 985
KERCKHOFF P.H.
TW EL 625
BASS LAKE
NP EL 3376
MILLERTON LAKE
P.G.&E.'s WILLOW CREEK POWER DEVELOPMENT NOT SHOWN
SQUAW DOME P.H.
FORKS P.H.
MAMMOTH P.H.
P.H. 1
P.H. 2
P.H. 2A
P.H. 3
P.H. 4
P.H. 8
WARD TUNNEL
SAN JOAQUIN RIVER
SOUTH FORK
MIDDLE FORK SAN JOAQUIN RIVER
NORTH FORK SAN JOAQUIN R
BIG CREEK
PIUTE CREEK
MONO CREEK
KAISER CREEK
JACKASS CREEK
GRANITE CREEK
CHIQUITO CREEK
WHISKEY CREEK
WILLOW CREEK
STEVENSON
SOUTH FORK MERCED RIVER
MONO COUNTY
FRESNO COUNTY
INYO COUNTY
MADERA COUNTY
MARIPOSA COUNTY
R21E
R22E
R23E
R24E
R25E
R26E
R27E
R28E
R29E
R30E
T4S
T5S
T6S
T7S
T8S
T9S
T10S

inflow to Millerton Lake. Feasibility studies should consider the points of view of the U. S. Bureau of Reclamation, Southern California Edison Company, and Pacific Gas and Electric Company, and evaluate the effect the proposed project would have on these agencies.

Major Project Features

This section contains descriptions and design considerations of the physical features of the proposed Upper San Joaquin River Project. These are described in separate groupings according to type of feature: (1) diversion dams and reservoirs, (2) storage dams and reservoirs, (3) tunnels and conduits, and (4) powerplants and penstocks.

Diversion Dams and Reservoirs. Approximately 75 percent of the runoff from the streams in the project area occurs from snowmelt from April through July. The U. S. Geological Survey records for the "Granite Creek Near Cattle Mountain" and the "North Fork San Joaquin River Below Iron Creek" stations show that peak mean daily flows, except on rare occasions during rainfloods, occur during the April through July snowmelt period; these snowmelt flows, therefore, were used in determining diversion dam and tunnel sites.

The diurnal fluctuations in streamflow discharge from snowmelt were analyzed. A copy of the recorder chart of "Granite Creek Near Cattle Mountain" for the period from April through July 1962 was obtained from the U. S. Geological Survey. The peak instantaneous flow on a given day during the snowmelt period was observed to be as great as 180 percent of the mean daily flow. The diversion tunnels as proposed are relatively long and expensive; therefore, economic analyses were made which indicated that it would be much less expensive to provide enough storage to regulate the daily fluctuations in streamflow at the diversion dams than to enlarge tunnels to carry 180 percent of the mean daily flow.

Diversion dams were sized to provide storage to translate daily fluctuations into constant flows, and tunnels were sized to divert and convey the mean daily flow. Preliminary designs were based on flows which occurred durring the moderately dry year of 1958-59 (60 percent of normal at Granite Creek and 68 percent of normal at North Fork San Joaquin River). Brief studies indicated this to be approximately the economical size. Some of the physical characteristics of features of the proposed diversion dams and reservoirs are shown in Table 45.

The proposed diversion dams on Iron Creek, North Fork San Joaquin River, and East Fork Granite Creek would be the concrete gravity type with an ungated ogee overpour section. The streambeds are in unweathered granite, and no construction problems are likely to be encountered. The topographic maps

TABLE 45

GENERAL FEATURES OF DIVERSION DAMS AND RESERVOIRS OF THE UPPER SAN JOAQUIN RIVER PROJECT

Feature	Diversion Dam and Reservoir			
	Iron Creek	North Fork San Joaquin River	East Fork Granite Creek	West Fork Granite Creek
Type of dam	Concrete gravity	Concrete gravity	Concrete gravity	Rockfill
Streambed elevation, in feet	7180	7110	7110	7025
Type of spillway	Ungated ogee weir	Ungated ogee weir	Ungated ogee weir	Ungated ogee weir
Spillway elevation, in feet	7200	7200	7120	7060
Type of outlet works:				
Stream outlet	18-inch slide gate	24-inch slide gate	24-inch slide gate	24-inch slide gate
Conduit intake	ungated	ungated	36-inch borehole	ungated

available for the diversion damsites are at such a small scale that estimates of quantities of concrete in the dams and estimates of the storage capacities of the reservoirs are only approximate; however, in the cost estimates, allowance is provided for adverse conditions.

The West Fork Granite Creek Diversion Dam would be a rockfill type with an impervious core. It would be more economical than the concrete gravity type because a chute-type spillway could be constructed in a saddle south of the right abutment.

Storage Dams and Reservoirs. The runoffs from streams flowing into the proposed storage reservoirs follow a pattern that is typical of streams in the high Sierras. Annual runoff varies widely from the estimated long-term (1907-08 through 1961-62) mean. At Chiquito Dam site it ranges from 25 percent (1930-31) to 230 percent (1937-38), and at Miller Crossing it ranges from 34 percent (1923-24) to 198 percent (1937-38) of the mean. During a typical water year, about 75 percent of the annual runoff is from snowmelt during April through July.

Because of the wide variation of streamflow, storage reservoirs are necessary to provide a dependable supply of water for power and other purposes.

The unimpaired mean annual runoff at the Miller Crossing site is estimated to be 436,000 acre-feet. With the project as proposed, an average of about 80,000 acre-feet would be diverted annually from the North Fork San Joaquin River into Jackass Reservoir, leaving an average of about 356,000 acre-feet at Miller Crossing.

Storage costs are relatively high at the Miller Crossing site because of topographic conditions, and the amount of head available for power can be considered as moderate (less than 800 feet). Studies indicate that it would not be economical to provide carryover storage from one water year to the next, and that the economical amount of storage would be approximately the amount necessary to provide project water during the eight-month historical dry periods from July through February in 1928-29 and 1929-30. The five-month dry period from July through November in 1931 would show a comparable reservoir storage requirement.

The mean annual inflow to the proposed Jackass Meadow Reservoir from the North Fork San Joaquin River and Granite Creek diversions, and from the natural flow of Jackass Creek, is about 180,000 acre-feet. Storage costs at Jackass Meadow would be less than at Miller Crossing, and a higher head is available for power (more than 2,800 feet). Storage would be provided to carry through a longer critical dry period than for the proposed Miller Crossing site, and a larger percentage of reservoir inflow would be developed as dependable yield. Storage was provided to meet power requirements during the 19-month critical dry period from July 1930 through January 1932. Additional storage at Jackass Meadow to give additional yield over a longer critical period would not be economically justified.

Storage costs at the Forks Reservoir site are higher than at the Miller Crossing site and the head available for power is less; therefore, comparatively less storage would be justified. Because of topographic conditions, storage costs rise sharply when storage exceeds 28,500 acre-feet. Studies indicate this capacity to be about the economic optimum.

At the Chiquito Reservoir site the required storage for streamflow regulation over the 19-month critical dry period from July 1930 through January 1932 coincides with favorable topographic conditions. The potential of surrounding lands for recreational development for this amount of storage is also favorable. Reconnaissance estimates indicate that these conditions establish the amount of economic storage.

On the basis of the design considerations described previously, the following amounts of storage are proposed at the four storage sites: (1) 95,000 acre-feet at Jackass Meadow, (2) 63,000 acre-feet at Miller Crossing, (3) 28,500 acre-feet at Forks, and (4) 35,000 acre-feet at Chiquito. The following paragraphs descri e the physical characteristics of these dams and reservoirs in more detail.

Jackass Meadow Dam. Jackass Meadow Dam would be located on Jackass Creek in Sections 23 and 24 of Township 5 South, Range 24 East, MDB&M, at a streambed elevation of 6,846 feet (see Plate 21). Three auxiliary dams would be required to raise the water surface to an elevation of 6,991 feet and to provide a gross storage of 95,000 acre-feet.

A preliminary geologic investigation indicates that the main damsite and the three auxiliary damsites are suitable for either a rockfill-type dam with an impervious core or a modified homogeneous earthfill type; furthermore, sufficient material for the dam embankments is available in the vicinity of the damsite. Impervious material occurs in the form of decomposed granite, and pervious material can be quarried from unweathered granitic rock. Preliminary designs and cost estimates indicate that modified homogeneous earthfill would be the more economical type of dam.

The proposed chute-type spillway would be located on the right abutment of the main dam near Jackass Butte.

The probable maximum flood would have a peak inflow of 12,000 second-feet from the 12.8 square miles of watershed. Because of the large water surface area of the reservoir (over 2,000 acres at the elevation of the spillway crest) the flood peak from the watershed would be reduced to an outflow of 1,580 second-feet. In designing the spillway it was assumed that the inflow from the North Fork of the San Joaquin River and Granite Creek Diversions would be at the maximum of 1,100 second-feet, resulting in a peak spillway discharge of 2,680 second-feet. The spillway was designed to pass this peak discharge with 3.2 feet of freeboard below the crest of the dam.

The Jackass Meadow Reservoir site is of gentle relief and is heavily timbered except in the meadow areas. The proposed reservoir would have a relatively large water surface area (2,020 acres at normal pool elevation) compared with other power reservoirs in the Sierra Nevada and would be relatively shallow, having a maximum drawdown from normal to minimum pool of 75 feet. Storage operation studies indidate that in moderately dry years, such as 1928-29 and 1929-30, the drawdown from normal pool by September 1 would be only about 10 feet, and in years with normal runoff the September 1 drawdown would be about 5 feet. These conditions present an extremely favorable situation for development of shoreline recreation facilities.

It is anticipated that there would be only a small net loss of water due to evaporation because evaporation from the proposed water surface would not be much greater than present evapotranspiration at the densely forested reservoir site.

Plate 21 presents the plan, profile, and maximum section of the proposed Jackass Meadow Dam, Table 46 lists information on the gneral features of the proposed dam and reservoir, and Table 47 lists the storage characteristics of the proposed reservoir.

Miller Crossing Dam. Miller Crossing Dam would be located on the Middle Fork San Joaquin River in the northeast quarter of Section 11, Township 5 South, Range 25 East, MDB&M. Streambed elevation at the damsite is 4,600 feet, feet, and the gross storage proposed for regulation of streamflow is 63,000 acre-feet.

A reconnaissance geological survey indicates the type of dam to be considered is limited by the availability of embankment materials. Pervious material in the form of unweathered granite is available in large quantities nearby, but impervious material is lacking. For these reasons the

TABLE 46

GENERAL FEATURES OF THE PROPOSED
JACKASS MEADOW DAM AND RESERVOIR

Features	Auxiliary Dam No. 1	Auxiliary Dam No. 2	Auxiliary Dam No. 3	Main Dam
Dam				
Type	earthfill	earthfill	earthfill	earthfill
Elevation of streambed or natural ground, in feet	6,960	6,887	6,984	6,825
Crest elevation, in feet	7,000	7,000	7,000	7,000
Crest height above streambed in feet	40	113	16	175
Crest length, in feet	2,240	2,530	840	2,750
Crest width, in feet	20	30	20	30
Slopes: Upstream face	3:1	3:1	3:1	3:1
Downstream face	2:1	2:1	2:1	2:1
Volume of fill, in cubic yards	202,100	2,089,100	15,700	1,750,100
Spillway				
Type				Chute
Crest elevation, in feet				6,991
Crest length, in feet				50
Freeboard above crest, in feet				9
Probable maximum flood peak outflow, in second-feet				2,680
Reservoir				
Storage capacity at minimum pool, in acre-feet				4,300
Storage capacity at normal pool, in acre-feet				95,000
Surface area at minimum pool, in acres				260
Surface area at normal pool, in acres				2,020
Water surface elevation at minimum pool, in feet				6,914
Water surface elevation at normal pool, in feet				6,991
Drainage area, in square miles				12.8

TABLE 47

AREAS AND CAPACITIES OF
PROPOSED JACKASS MEADOW RESERVOIR

Depth of Water, in Feet	Water Surface Elevation, in Feet	Water Surface Area, in Acres	Storage Capacity, in Acre-feet
0	6,825	0	0
10	6,835	5	50
20	6,845	7	100
30	6,855	10	200
40	6,865	15	300
50	6,875	20	400
60	6,885	43	900
70	6,895	83	1,650
80	6,905	140	2,600
90	6,915	240	4,700
100	6,925	490	8,500
110	6,935	790	14,500
120	6,945	1,045	23,500
130	6,955	1,290	35,000
140	6,965	1,515	49,000
150	6,975	1,730	65,000
160	6,985	1,910	83,000
170	6,995	2,080	103,000
175	7,000	2,150	114,000

type of dam selected is rockfill with a concrete face similar to the Pacific Gas and Electric Company's Wishon and Courtright Dams.

The proposed chute-type spillway with an ungated, ogee overpour crest would be located in the right abutment. The type and location of spillway was selected because of topographic conditions. The spillway would require a large amount of excavation; however, the excavated material would be competent unweathered granitic rock suitable for inclusion in the dam embankment.

The spillway, 300 feet long, would pass 100,000 second-feet (the estimated peak discharge from the probable maximum flood) with three feet of freeboard below the crest of the dam.

During construction of the dam embankment, streamflow would be diverted through a 19-foot-diameter lined horseshoe tunnel beneath the right abutment. This tunnel would subsequently be used as the first section of the power tunnel as well as a conduit for releases to the stream below the dam for the maintenance and/or enhancement of the river fishery.

Except for about 100 acres of flat land just upstream from the damsite (indicated as Pine Flat on U. S. Geological Survey maps), the topography of the Miller Crossing Reservoir site is of sharp relief. At normal pool elevation all the relatively flat areas in the reservoir site would be inundated and the shoreline would be mostly of steep, unweathered granite with very little timber cover. The proposed reservoir would provide little opportunity for the development of recreation facilities.

Plate 22 presents the plan, profile, and maximum section of the proposed Miller Crossing Dam, Table 48 lists information on the general features of the proposed dam and reservoir, and Table 49 lists the storage characteristics of the proposed reservoir.

Forks Dam. Forks Dam would be located on the San Joaquin River about one-quarter mile downstream from the confluence of the South amd Middle Forks of the San Joaquin River near the center of Section 4, Township 6 South, Range 25 East, MDB&M. Streambed elevation at the damsite is 3,700 feet, and the proposed 270-foot dam would impound 28,500 acre-feet of water.

The proposed reservoir would receive the regulated releases from Jackass Meadow and Miller Crossing Reservoirs and the natural runoff from 135 square miles of undeveloped watershed.

TABLE 48

GENERAL FEATURES OF THE PROPOSED
MILLER CROSSING DAM AND RESERVOIR

Feature	Description
Dam	
Type	Rockfill with concrete face
Elevation of streambed, in feet	4,600
Crest elevation, in feet	4,925
Crest height above streambed, in feet	325
Crest length, in feet	1,010
Crest width, in feet	20
Slopes: Upstream face	1:1, 1.2:1 and 1.3:1
Downstream face	1.4:1
Volume of fill, in cubic yards	1,962,600
Spillway	
Type	Chute
Crest elevation, in feet	4,905
Crest length, in feet	300
Freeboard above crest, in feet	20
Probable maximum flood peak outflow, in second-feet	100,000
Reservoir	
Storage capacity at minimum pool, in acre-feet	3,000
Storage capacity at normal pool, in acre-feet	63,000
Surface area at minimum pool, in acres	90
Surface area at normal pool, in acres	450
Water surface elevation at minimum pool, in feet	4,650
Water surface elevation at normal pool, in feet	4,905
Drainage area, in square miles	254

TABLE 49

AREAS AND CAPACITIES OF
PROPOSED MILLER CROSSING RESERVOIR

Depth of Water, in Feet	Water Surface Elevation, in Feet	Water Surface Area, in Acres	Storage Capacity, in Acre-feet
0	4,600	0	0
20	4,620	32	1,250
40	4,640	65	2,500
60	4,660	98	3,750
80	4,680	130	5,000
100	4,700	147	8,000
120	4,720	167	11,000
140	4,740	188	14,500
160	4,760	210	18,500
180	4,780	230	23,000
200	4,800	250	27,750
220	4,820	280	33,250
240	4,840	310	39,000
260	4,860	350	45,500
280	4,880	395	53,000
300	4,900	445	61,400
320	4,920	490	70,500
325	4,925	500	73,000

No geologic survey was made of the Forks Dam site. Aerial photographs taken by the Department, to a scale of one inch equals 1,500 feet, indicate that the abutments at the damsite are unweathered granite with the possibility of minor amounts of talus on the lower right abutments; and that moderate amounts of streambed deposits may be expected in the channel section. Because knowledge of the geology is uncertain, cost estimates of the proposed dam include allowances for unforeseen contingencies.

There appear to be no substantial quantities of impervious fill material in the vicinity of the proposed dam; however, large amounts of pervious material in the form of unweathered granitic rock are near the damsite. The availability of material indicates that a rockfill dam with a concrete face would be the best choice.

Topographic conditions are very favorable for a spillway to be located in a saddle south of the left abutment. A natural re-entry to the river would return spills to the river channel approximately 1,000 feet downstream from the axis of the dam. The spillway would have a 450-foot ogee weir overpour crest and would discharge the estimated 150,000 second-foot peak outflow of the probable maximum flood with three feet of freeboard below the crest of the dam.

During construction of the proposed dam embankment streamflows would be diverted by a 22-foot-diameter lined horseshoe tunnel beneath the right abutment. This tunnel would later be used to house the river and power tunnel outlet works.

At normal pool elevation the small amount of relatively flat land in the reservoir site would be inundated and the shoreline would be of precipitous unweathered granitic rock with virtually no vegetative cover. Recreation potential appears to be poor. Plate 22 presents the plan, profile, and maximum section of the proposed Forks Dam, Table 50 lists information on the general features of the proposed dam and reservoir, and Table 51 lists the storage characteristics of the proposed reservoir.

Chiquito Dam. Chiquito Dam would be located on Chiquito Creek in the southwest quarter of Section 8 and the northwest quarter of Section 17, Township 6 South, Range 24 East, MDB&M. The gross storage proposed for regulation of streamflow is 35,000 acre-feet.

A preliminary geological reconnaissance survey indicates that the site is suitable for either a rockfill dam with an impervious core or a modified homogeneous earthfill dam. The abutments are of massive, unweathered granite.

TABLE 50

GENERAL FEATURES OF THE PROPOSED
FORKS DAM AND RESERVOIR

Feature	Description
Dam	
Type	Rockfill with concrete face
Elevation of streambed, in feet	3,680
Crest elevation, in feet	3,950
Crest height above streambed, in feet	270
Crest length, in feet	590
Crest width, in feet	20
Slopes: Upstream face	1:1, 1.2:1, and 1.3:1
Downstream face	1.4:1
Volume of fill, in cubic yards	790,700
Spillway	
Type	Concrete over-pour
Crest elevation, in feet	3,930
Crest length, in feet	500
Freeboard above crest, in feet	20
Probable maximum flood peak outflow, in second-feet	150,000
Reservoir	
Storage capacity at minimum pool, in acre-feet	2,500
Storage capacity at normal pool, in acre-feet	28,500
Surface area at minimum pool, in acres	60
Surface area at normal pool, in acres	290
Water surface elevation at minimum pool, in feet	3,774
Water surface elevation at normal pool, in feet	3,930
Drainage area, in square miles	850

TABLE 51

AREAS AND CAPACITIES OF
PROPOSED FORKS RESERVOIR

Depth of Water, in Feet	Water Surface Elevation, in Feet	Water Surface Area, in Acres	Storage Capacity, in Acre-feet
0	3,680	0	0
20	3,700	6	200
40	3,720	18	500
60	3,740	34	1,000
80	3,760	49	1,700
100	3,780	65	2,900
120	3,800	83	4,500
140	3,820	108	6,400
160	3,840	143	8,600
180	3,860	181	11,600
200	3,880	215	15,500
220	3,900	249	20,300
240	3,920	276	25,500
260	3,940	304	31,500
270	3,950	318	38,500

Impervious material in the form of decomposed granite and pervious material in the form of unweathered granitic rock are available in adequate quantities near the damsite. Studies indicate that a rockfill dam with an impervious core would be the more economical because the flatter upstream slope of a modified homogeneous earthfill would extend the upstream portion of the dam to a widened section between abutments and require considerably more embankment material.

The Chiquito Dam site has almost ideal topographic and geologic conditions for the spillway. The right abutment of the dam would be at about the same elevation as the dam crest, and the stream curves about 180 degrees around the right abutment. The right abutment is of massive unweathered granitic rock which would be very resistant to the erosive effect of water flowing at high velocities. Very little excavation for the spillway would be required, and a small retaining wall at the right end of the dam would direct spills over the abutment into the streambed below the dam. A small concrete ogee weir section would top the entire length (450 feet) of the overpour section. The spillway would discharge the estimated 48,000-second-foot peak outflow from the probable maximum flood with three feet of freeboard below the crest of the dam.

During construction the stream would be diverted through an eight-foot-diameter horseshoe tunnel beneath the right abutment. The diversion tunnel would subsequently be used to house the outlet works.

The Chiquito Reservoir site is comparatively flat and moderately timbered. With the normal pool elevation as proposed, large areas around the shoreline would be suitable for the development of camping and picnicking facilities. A larger reservoir would inundate most of these areas.

Plate 23 presents the plan, profile, and maximum section of the proposed Chiquito Dam, Table 52 lists information on the general features of the proposed dam and reservoir and Table 53 lists the storage characteristics of the proposed reservoir.

<u>Tunnels and Conduits</u>. Separate criteria were used in making preliminary designs of diversion and power tunnels and conduits. These diversion facilities, in conjunction with the diversion dams and reservoirs, would divert the natural runoff of Iron Creek, the North Fork San Joaquin River, East Fork Granite Creek, and West Fork Granite Creek into Jackass Meadow Reservoir. The power tunnels and conduits would convey water from the reservoirs (Jackass Meadow, Miller Crossing, and Forks) to the penstocks for power development.

TABLE 52

GENERAL FEATURES OF THE PROPOSED
CHIQUITO DAM AND RESERVOIR

Feature	Description
Dam	
Type	Rockfill, impervious core
Elevation of streambed, in feet	4,790
Crest elevation, in feet	4,960
Crest height above streambed, in feet	170
Crest length, in feet	1,090
Crest width, in feet	40
Slopes: Upstream face	2:1
Downstream face	2:1
Volume of fill, in cubic yards	881,000
Spillway	
Type	Chute
Crest elevation, in feet	4,948
Crest length, in feet	450
Freeboard above crest, in feet	12
Probable maximum flood peak outflow, in second-feet	48,000
Reservoir	
Storage capacity at minimum pool, in acre-feet	5,000
Storage capacity at normal pool, in acre-feet	35,000
Surface area at minimum pool, in acres	95
Surface area at normal pool, in acres	540
Water surface elevation at minimum pool, in feet	4,877
Water surface elevation at normal pool, in feet	4,948
Drainage area, in square miles	38

TABLE 53

AREAS AND CAPACITIES OF
PROPOSED CHIQUITO RESERVOIR

Depth of Water, in Feet	Water Surface Elevation, in Feet	Water Surface Area, in Acres	Storage Capacity, in Acre-feet
0	4,790	0	0
10	4,800	4	30
20	4,810	10	130
30	4,820	16	230
40	4,830	34	570
50	4,840	52	910
60	4,850	74	1,650
70	4,860	97	2,390
80	4,870	149	3,995
90	4,880	224	5,600
100	4,890	280	8,900
110	4,900	336	11,200
120	4,910	399	15,185
130	4,920	462	19,170
140	4,930	523	24,390
150	4,940	584	29,610
160	4,950	648	36,085
170	4,960	712	42,560

Both types of tunnels (diversion and power) would be unlined horseshoe sections. Tunneling conditions are expected to be good along the routes of the proposed tunnels. The proposed power tunnels would be entirely in granitic rock. The diversion tunnels would be in both granitic and metamorphic rock. Experience by the Southern California Edison Company has shown that this type of tunnel performs well, requires very little maintenance, and costs substantially less than those of lined sections6/. It is conservatively estimated that approximately five percent of the length of the proposed tunnels, excluding the portals, would require lining.

Diversion Tunnels and Conduits. Diversion tunnels and conduits would be sized to convey the maximum mean daily flows which are estimated to have occurred during the 1958-59 water year. These mean daily flows are estimated to have been as follows: (1) 100 second-feet at Iron Creek Diversion; (2) 400 second-feet at North Fork San Joaquin River Diversion; (3) 250 second-feet at East Fork Granite Creek Diversion; and (4) 350 second-feet at West Fork Granite Creek Diversion. The accumulation of diversions resulted in estimated capacities of 100 second-feet from Iron Creek to North Fork San Joaquin River, 500 second-feet from there to East Fork Granite Creek, 750 second-feet from there to West Fork Granite Creek, and 1,100 second-feet from there into the proposed Jackass Meadow Reservoir.

A conduit would be provided to convey flows in a 1,600-foot reach between the East and West Forks of Granite Creek where the topography is such that an inverted siphon would be required. Although no reconnaissance geological survey was made of the conduit route, it appears that either reinforced concrete pipe or steel pipe would be suitable. The pipe would have to be buried to prevent freezing during the winter. The topography along the route of the proposed conduit is flat and heavily timbered, indicating a good soil cover; therefore, a large amount of rock excavation is not likely to be required.

Power Tunnels and Conduits. Power tunnels would have the same physical structure (unlined horseshoe) as the diversion tunnels. The economical size was estimated from considerations of the yield of the reservoir, the value of power and the costs of tunnel and penstock (including the

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6/ Journal of the Power Division, Proceedings of the American Society of Civil Engineers "Unlined Tunnels of the Southern California Edison Company", Paper 4087, October 1964.

value of losses of head through the power conduit). Preliminary designs of power facilities were based on an estimated future economic demand for project power in the general 30-percent portion of the load curve. The proposed Forks power tunnel and penstock capacities were determined from the estimated dependable yield of the 28,500-acre-foot reservoir and a 30-percent annual capacity factor.

The combined Jackass and Miller Units of the Squaw Dome Powerplant would be capable of producing the required minimum kilowatt-hours per kilowatt of dependable capacity; however, it was found economically advantageous to unbalance the capacity factors of the two units.

The annual dependable yield for power of the proposed Miller Crossing Reservoir is relatively small (133,000 acre-feet) compared with the mean annual inflow (356,000 acre-feet). As stated previously, the high cost of storage at the Miller Crossing site limited the economical amount of storage and therefore limited the yield. If tunnel and penstock sizes were based on the dependable annual yield and a 30-percent capacity factor, the maximum monthly release for power would be 36,500 acre-feet, and the dependable generating capacity would be 35,000 kilowatts. Studies indicated that under this condition spills would occur during years when the runoff exceeds 60 percent of normal. Further studies indicated that it would be economically advantageous to size the power facilities 50 percent larger. This corresponds to sizing at a 20-percent annual capacity factor. The maximum monthly power release would then be 55,000 acre-feet and the installed generating capacity would be 52,000 kilowatts, which results in an average of 16 percent more usable energy being produced.

At the proposed Jackass Meadow Reservoir, the annual dependable yield for power is relatively large (106,000 acre-feet) compared with the mean annual inflow (180,000 acre-feet). Furthermore, extremes in annual inflow are not so pronounced as at Miller Crossing because about 90 percent of the inflow is from diversions which bypass water during normal and wet years. If tunnel and penstock sizes were based on the dependable annual yield and a 30-percent annual capacity factor, the dependable generating capacity would be 102,000 kilowatts. Studies indicate that power facilities could be reduced in size with very little loss in usable energy. A reduction in the powerplant installed capacity to 85,000 kilowatts results in a decrease in the production of usable energy of only 0.2 percent. The decrease in installed capacity of the Jackass Unit equals the increase in installed capacity of the Miller Unit.

Estimates indicate that the cost of increasing the size of the tunnel, penstock, and powerplant of the Miller Unit of the Squaw Dome Powerplant as proposed is approximately equal to the saving by reducing the size of the tunnel, penstock, and powerplant of the Jackass Unit. Thus an appreciable amount of usable energy could be produced at no increase in project cost.

The Miller Unit, with a dependable capacity of 52,000 kilowatts operating at a 20-percent capacity factor, and the Jackass Unit with a dependable capacity of 85,000 kilowatts operating at a 36-percent capacity factor, would correspond to a dependable capacity of 137,000 kilowatts operating at a 30-percent capacity factor.

Plate 19 shows the layout and the approximate alignments of the proposed tunnels and conduits, and Plate 20 shows profiles of the tunnels and conduits indicating conveyance capacities, diameters, and lengths. Table 54 presents pertinent statistical information regarding the proposed tunnels and conduits.

Powerplants and Penstocks. Powerplant sizes were determined from the reservoir yields and heads available during critical dry periods and from annual plant capacity factors indicated above. A further study at the feasibility level may indicate that additional installed capacity may be economically justified.

All the proposed powerplants in this reconnaissance level investigation would be housed in conventional surface structures. A more detailed investigation may indicate that underground installations would be less costly. The turbines at the proposed Miller Unit of the Squaw Dome Powerplant and at the Forks Powerplant would be of the Francis type. The turbines at the Miller Unit would have a shallow setting because no increase in head would be gained from a lowering of the water surface in the proposed Forks Reservoir. On the other hand, the Forks turbines would have a deep setting in order to utilize a significant increase in head available at times when Mammoth Pool Reservoir is drawn down.

The proposed Jackass Unit of the Squaw Dome Powerplant would have impulse-type turbines. The average head of 2,871 feet would make the plant one of the highest head plants in the world.

All the proposed penstocks in this reconnaissance level investigation were considered to be of the conventional surface type and to be of welded construction using ASTM A 285, Grade B, firebox quality steel. A more detailed investigation may indicate that an economic advantage could be attained with other types of construction, such as using higher strength steel or placing penstocks underground.

TABLE 54

GENERAL FEATURES OF PROPOSED TUNNELS AND CONDUITS OF THE UPPER SAN JOAQUIN RIVER PROJECT

Feature	Description
I. Diversion Tunnels and Conduits	
A. Iron Creek to North Fork (Conduit)	
Type	Welded steel pipe
Diameter, in inches	36
Length, in feet	1,700
Capacity, in second-feet	100
B. North Fork San Joaquin to East Fork Granite Creek (Tunnel)	
Type	Unlined horseshoe
Diameter, in feet	10.7
Length, in miles	5.42
Capacity, in second-feet	500
C. East Fork Granite Creek to West Fork Granite Creek (Tunnel and Conduit)	
Tunnel type	Unlined horseshoe
Tunnel diameter, in feet	12.2
Tunnel length, in miles	0.8
Tunnel capacity, in second-feet	750
Conduit type	Reinforced concrete pipe
Conduit diameter, in feet	8.0
Conduit length, in miles	0.3
Conduit capacity, in second-feet	750
D. West Fork Granite Creek to Jackass Meadow Reservoir (Tunnel)	
Type	Unlined horseshoe
Diameter, in feet	14.3
Length, in miles	3.15
Capacity, in second-feet	1,100

TABLE 54 (Continued)

GENERAL FEATURES OF PROPOSED TUNNELS AND CONDUITS OF THE UPPER SAN JOAQUIN RIVER PROJECT

Feature	Description
II. Power Tunnels and Conduits	
A. Jackass Meadow Reservoir to Squaw Dome (Tunnel and Conduit)	
Tunnel type	Unlined horseshoe
Tunnel diameter, in feet	11.3
Tunnel length, in feet	9,400
Tunnel slope	0.002
Tunnel capacity, in second-feet	404
Conduit type	Reinforced concrete pipe
Conduit diameter, in feet	8.0
Conduit length, in feet	2,300
Conduit slope	0.002
Conduit capacity, in second-feet	404
B. Miller Crossing Reservoir to Squaw Dome (Tunnel)	
Type	Unlined horseshoe
Diameter, in feet	15.3
Length, in feet	19,800
Slope	0.002
Capacity, in second-feet	918
C. Forks Reservoir to Mammoth Pool Reservoir (Tunnel)	
Type	Unlined horseshoe
Diameter, in feet	17.2
Length, in feet	19,800
Slope	0.002
Capacity, in second-feet	1,245

Note: Manning's "n" values used in design are 0.035 for unlined tunnels, 0.013 for reinforced concrete pipe, and 0.011 for welded steel pipe.

In estimating the required thickness of the proposed penstocks the design head was considered to be 20 percent greater than the maximum static head, to allow for surge.

The proposed penstocks range in capacity and size from 404 second-feet and 4.8 feet at the Jackass Unit of the Squaw Dome Powerplant to 1,245 second-feet and 9.4 feet at the Forks-Mammoth Pool power drop.

Plate 19 shows the locations of the proposed powerplants and the approximate alignment of the proposed penstocks, and Plate 20 shows a profile of the proposed penstocks giving diameters, lengths, and carrying capacities. Table 55 presents further statistical information.

Recreation

Chiquito and Jackass Meadow Reservoir sites would offer good recreation opportunities; however, no studies have been made of Miller Crossing and Forks Reservoirs. It appears that limited access and steepness of surrounding topography would limit the potentials at Miller Crossing and Forks. Further recreation studies are needed to evaluate the recreation potentials of these proposed reservoirs.

Chiquito Reservoir. This reservoir would have excellent recreation potential for several reasons: (1) The reservoir would be at an elevation of 4,948 feet, thus providing an ideal summertime climate. (2) Access to the reservoir would be very good, since an existing paved two-lane road passes within two miles of the reservoir site. (3) The reservoir site is in a moderately timbered region of the Sierra National Forest with approximately 400 acres of relatively flat land surrounding the reservoir which would be suitable for overnight camping and for picnicking. (4) Under the proposed operation, the reservoir water surface would be held at a very constant level throughout the recreation season, with about two feet of drawdown by the end of September. (5) The watershed which contributes runoff to the reservoir slopes to the south and averages about 7,000 feet elevation, resulting in an early snowmelt runoff. By July the water near the surface would be warm enough to make the proposed reservoir pleasant for swimming and water skiing.

Jackass Meadow Reservoir. This proposed reservoir would be at an elevation approximately 2,000 feet higher than the proposed Chiquito Reservoir. Recreation potential is considered to be excellent. Access to the site is good, although not so favorable as access to the proposed Chiquito Reservoir. Large areas above the northern shoreline are relatively flat and heavily timbered and are therefore suitable for camping. Temperatures at night during the summer

TABLE 55

GENERAL FEATURES OF PROPOSED POWERPLANTS AND PENSTOCKS OF THE UPPER SAN JOAQUIN RIVER PROJECT

Feature	Description
I. POWERPLANTS	
Squaw Dome Powerplant (2 Units)	
Combined installed capacity in kilowatts	137,000
Composite capacity factor during critical dry cycle, in percent	30
Combined dependable capacity, in kilowatts	137,000
Jackass Unit:	
Turbine type	Impulse
Overall unit efficiency, in percent . .	86
Installed capacity, in kilowatts	85,000
Average effective head during critical dry cycle, in feet	2,871
Unit capacity factor during critical dry cycle, in percent	36
Miller Unit:	
Turbine type	Francis
Overall unit efficiency, in percent . .	87
Installed capacity, in kilowatts	52,000
Average effective head during critical dry cycle, in feet	772
Unit capacity factor during critical dry cycle, in percent	20
Forks Powerplant	
Turbine type	Francis
Overall plant efficiency, in percent	87
Installed capacity, in kilowatts	54,000
Average effective head during critical dry cycle, in feet	589
Capacity factor during critical dry cycle, in percent	30

TABLE 55 (Continued)

GENERAL FEATURES OF PROPOSED POWERPLANTS AND PENSTOCKS OF THE UPPER SAN JOAQUIN RIVER PROJECT

Feature	Description
II. PENSTOCKS	
Squaw Dome Penstocks	
Types	Welded steel
Combined design capacities, in second-feet	1,322
Jackass Unit:	
Length, in feet	6,770
Average diameter, in feet	4.8
Design capacity, in second-feet . . .	404
Miller Unit:	
Length, in feet	1,450
Average diameter, in feet	8.1
Design capacity, in second-feet . . .	918
Forks Penstock	
Type	Welded steel
Design capacity, in second-feet	1,245
Length, in feet	1,110
Average diameter, in feet	9.4

Note: Manning's "n" value of 0.011 was used in the design of penstocks.

may drop to 40 degrees Fahrenheit, but daytime temperatures would be higher.

During the latter part of July and during August of most years, releases would be made only for minimum power requirements and for stream fisheries. Reservoir water surface elevations would be fairly constant. The drawdown would be about ten feet by September 1 during dry years and about five feet during normal and wet years.

The reservoir water temperatures would be colder than at the proposed Chiquito Reservoir. Although the watershed area contributing runoff to the reservoir slopes southward, it is at extremely high elevations that range from 7,000 feet at the reservoir to over 13,000 feet at crest of the Ritter Range. Use of the reservoir for water-contact sports would be for the more hardy individuals.

While the proposed reservoir would not be desirable for water-contact sports, it should be popular for fishing and boating. Because of the large, unobstructed water surface area of the proposed reservoir, it should become popular for sailboating, as is Huntington Lake.

Miller Crossing and Forks Reservoirs. Topography and the proposed storage operation appear to be unfavorable for recreation development at the Miller Crossing and Forks Reservoir sties. The proposed reservoirs would inundate all the flat lands in the sites leaving steep walls of unweathered granite rock with very little vegetative cover as shorelines. Because the shorelines are steep, the water surface areas would change little but water surface levels would fluctuate widely during the recreation season. Additional recreation studies will be necessary to determine whether there are appreciable recreation potentials at these sites.

Fish and Wildlife

This investigation has not included detailed studies of the effect of the proposed Upper San Joaquin River Project on fish and wildlife. Limited appraisals indicate that the effects would be detrimental in some instances and beneficial in others.

The fisheries in the streams below proposed Jackass Meadow and Chiquito Reservoirs could be enhanced because fish releases would be greater than the natural flow of the streams during the late summer and fall. Furthermore, the proposed reservoirs could provide substantial fisheries themselves.

On the other hand, the proposed project would probably be detrimental to the fisheries below the proposed North Fork Diversion, Miller Crossing, and Forks Dam because the existing stream flow would be reduced. A more detailed study at the feasibility level should consider more thoroughly the beneficial and detrimental effects of the proposed project on the existing fisheries.

The proposed Jackass Meadow and Chiquito Reservoirs would be on the migration route of the San Joaquin Deer Herd and would alter the migration route. Conduits of the proposed project would not interfere with the passage of wildlife because the conduits would all be underground. Deer fawning areas would be lost at the Jackass Reservoir site. A more detailed study should be made at the feasibility level to determine fully the effect of the proposed project on wildlife, and to plan enhancement features

Proposed Operation

Power releases from the proposed Jackass Meadow, Miller Crossing, and Forks Reservoirs would be of sufficient quantity to always meet the minimum power requirements given in Table 56. Assuming a repetition of the runoff that occurred during the period 1907-08 through 1961-62, releases would be greater than necessary to meet the minimum requirements and secondary power would be produced in all years except for the critical dry period.

Under the proposed operation, the reservoirs would be drawn down below levels which would occur during the critical dry period only when snowmelt runoff forecasts indicate it would be safe. At Jackass Meadow Reservoir, where it would be desirable to hold the reservoir water surface to as constant a level as possible during the recreation season, releases for primary power only would be made in July, August, and September. At Forks and Miller Crossing Reservoirs, releases would be made for secondary power during July, August, and September if it were considered advantageous. Releases from all three reservoirs during October, November, and December would be made for secondary power to the extent that such releases would not result in less storage than occurred during the same months of the critical dry period. Releases during January, February, and March would be influenced by snowmelt runoff forecasts, and secondary power may or may not be produced. During most years, reservoir storage would be at a minimum on the first of April in order to reduce spills from the April through July snowmelt runoff. This would result in a greater amount of secondary power being produced. Tables A-5, A-6, and A-7 of Appendix A show the proposed operations of Jackass Meadow, Miller Crossing, and Forks Reservoirs during the critical dry period.

TABLE 56

MINIMUM MONTHLY POWER REQUIREMENTS
AT A 30 PERCENT ANNUAL CAPACITY FACTOR

Month	Minimum Requirements	
	Kilowatt Hours per Kilowatt of Dependable Capacity	Percent of Annual Kilowatt Hours
October	200	7.60
November	170	6.46
December	180	6.84
January	160	6.08
February	140	5.32
March	180	6.84
April	200	7.60
May	210	8.00
June	270	10.27
July	340	12.93
August	340	12.93
September	240	9.13
Totals	2,630	100.0

The power releases shown in the tables for primary power were based on average reservoir water surface elevations during the critical dry period. Under actual operation, the releases would be smaller when storage is greater than average; conversely, the releases would be greater when storage is less than average. A more complicated storage operation did not appear to be justified in this reconnaissance investigation because experience has shown that there would be only a small difference in estimated dependable power.

Streamflow releases would normally be a minimum of 600 acre-feet per month from Jackass Meadow Reservoir, 1,200 acre-feet per month from Miller Crossing Reservoir, and 1,800 acre-feet per month from Forks Reservoir. During a critical dry period, the releases would be reduced by 50 percent.

Releases from the proposed Chiquito Reservoir would not be made directly to power facilities; therefore, there is no need to release according to a power schedule. Releases would be made into the stream below the dam from where they would flow into Mammoth Pool Reservoir. Under the proposed operation, 26,400 acre-feet would be released during the four-month period from October through January of each water year. Mammoth pool would always be drawn down during this period and would be able to regulate the Chiquito release for downstream power production. Releases in addition to fish requirements may or may not be made in February and March, depending upon snowmelt runoff predictions. The reservoir would fill during May or June in all but very dry years such as 1923-24, 1930-31, 1933-34, and 1961-62. Only fish releases would be made during the recreation season from June through September. Some spill would occur during normal and wet years in June and July because inflows would exceed fish release requirements.

The proposed operation greatly enhances the recreation potential of the proposed Chiquito Reservoir because of the constant water surface elevation during the recreation season. The drawdown by October first due to evaporation and fish releases would be only about two feet. Table A-8 of Appendix A presents the proposed operation of Chiquito Reservoir during the critical dry period.

Estimates were made of the average amounts of energy that would be produced by the proposed project assuming the same historical flow that occurred during the 50-year period from 1907-08 through 1956-57. The average amount of energy produced would be 851 million kilowatt-hours annually, and would range from 502 million kilowatt-hours in 1923-24 and 1930-31 to 1,138 million kilowatt-hours in 1937-38. Table A-9 presents the estimated annual energy production for the 50-year period from 1907-08 through 1956-57.

Project Benefits

The proposed Upper San Joaquin River Project would produce hydroelectric energy, provide recreation opportunity, increase the yield of dependable irrigation water, provide stream releases for maintenance and enhancement of stream fisheries, and provide other associated project benefits. A reconnaissance level appraisal of these benefits is presented in the following sections.

Power

Power benefits would be derived from the sale of power produced in project powerplants and from increasing the usable energy of existing downstream powerplants. The dependable capacity of the existing downstream power development would also be increased by the release from storage in project reservoirs, but this has not been evaluated.

Revenues from power sales are estimated from two components: dependable generating capacity and usable energy production. The project as proposed would have a dependable capacity, at a 30-percent annual capacity factor, of 191,000 kilowatts and would produce an annual average of 851 million kilowatt-hours of usable energy. The estimated annual production of hydroelectric energy is shown in Table A-9 of Appendix A.

The additional regulation of streamflow provided by the proposed project would benefit existing downstream power development in two ways. Studies indicate that spills will occur at the existing Mammoth Pool Reservoir during the snowmelt period of April through July in years when the natural runoff of the San Joaquin River at Friant exceeds about 1,130,000 acre-feet. This quantity of runoff is exceeded in 42 years of the 55-year historical period from 1907-08 through 1961-62, or about 76 percent of the time. Under the proposed project operation, spills would generally be eliminated at Mammoth Pool during years when the natural runoff at Friant was less than 1,750,000 acre-feet. Spills would be reduced on the average by 196,500 acre-feet during years when the natural runoff at Friant exceeded 1,750,000 acre-feet. An estimated annual average increase of 106,000 acre-feet of water would be made available for power below Mammoth Pool because of the regulation provided by the 221,500-acre-foot storage of the proposed project. This would produce an additional 179 million kilowatt-hours of usable energy.

Increases in dependable capacities of existing downstream powerplants were not included as project benefits. A more detailed study, at the feasibility level, should evaluate this increase. The additional energy produced in downstream powerplants was estimated to have a value of 2.75 mills per kilowatt-hour.

The estimated power benefits are presented in Table 57. The unit values used in estimated power revenues were 16 dollars per year per kilowatt of dependable capacity and 2.75 mills per kilowatt-hour of usable energy produced.

TABLE 57

ESTIMATED AVERAGE ANNUAL POWER BENEFITS OF THE PROPOSED UPPER SAN JOAQUIN RIVER PROJECT

Source	Dependable Capacity		Usable Energy		Total Revenue
	Kilowatts	Revenue	Millions of Kilowatt Hours	Revenue	
Squaw Dome					
Jackass Unit	85,000	$1,360,000	400.30	$1,100,800	$2,460,800
Miller Unit	52,000	832,000	184.11	506,300	1,338,300
Forks	54,000	864,000	266.30	732,300	1,596,300
Southern California Edison Company	Not Determined		162.12	445,800	445,800
Pacific Gas and Electric Company	Not Determined		17.73	48,800	48,800
Total average annual power revenue					$5,890,000

Recreation

A monetary evaluation of recreation benefits to be provided by the proposed project was not made, although such benefits would be substantial because of the excellent potentials of two of the reservoirs. A general description of recreation benefits was included under a previous section describing the recreation aspects of the proposed project.

Water Conservation

Substantial conservation benefits would accrue to the proposed project even though releases from three of the proposed reservoirs would be made on a power schedule. Uncontrolled spills from Millerton Lake would be reduced in wet years by storage in project reservoirs, and carry-over storage released from these reservoirs would increase the available supply during dry years. Evaluation of conservation benefits was considered beyond the scope of this investigation.

Fish and Wildlife

As in the case of recreation, fish and wildlife benefits were not evaluated in this investigation but should be if a more detailed investigation is made. From a brief examination, it appears that both benefits and detriments would result from the proposed project.

Cost Estimates

The capital costs of project features were estimated in the following manner: The costs of major construction items were computed by multiplying the quantities (as estimated in the preliminary designs) by the estimated unit costs and adding 15 percent to allow for minor items not estimated and for unforeseen construction difficulties. A total, representing the construction cost, was thus obtained. To the construction cost, 15 percent was added to allow for engineering, legal, and administration costs, and a new subtotal was obtained. To this subtotal, interest during construction was added to obtain the estimated capital cost.

In estimating the cost of dams, the major construction items considered were: (1) diversion of streamflow during construction, (2) stripping of dam foundation areas, (3) excavation of cut-off trench, (4) grouting of foundation, (5) excavation of borrow material, (6) hauling and placing of material for dam embankments, (7) construction of spillway (including excavation, weirs, and structures), and (8) construction of outlet works (including excavation, structures, gates, and valves).

Major items considered in the cost of reservoirs are clearing and grubbing, access roads, construction roads, and relocation of existing roads.

In tunnel construction, major items include excavation quantities for the tunnels, adits, and, in the case of power tunnels, surge chambers. Consideration was given to tunnel size, distance between headings, and tunneling conditions.

Penstock cost estimates were based entirely on the weight of the penstock as computed from preliminary designs. Pipeline costs were estimated by multiplying the length in feet by the unit cost per lineal foot. Powerplant costs were estimated from the installed capacities as determined in the preliminary designs.

Unit costs used in estimating the cost of dams and reservoirs were derived from recent bids on comparable projects and from updating unit costs used in prior investigations. Unit costs for tunnel excavation were taken from curves prepared by the Department which were developed for similar tunneling conditions. The unit costs were updated using U. S. Bureau of Reclamation cost indices to reflect current costs. Unit costs for penstocks and powerplants were derived in like manner. Pipeline unit costs were derived from current construction bids with due consideration given the remoteness and topography of the project area.

Table 58 presents a summary of the capital costs of the proposed project features.

Estimates of annual cost of the proposed project features were computed on the basis of four percent interest and amortization over a 50-year period. Total annual costs include amortization, replacement, operation and maintenance, general expense, and insurance. Table 59 presents a summary of the annual costs of the proposed project.

Comparison of Benefits and Costs

The upper San Joaquin River Project is justified in that the total annual power benefits were estimated to be $5,890,000 and the total annual costs were estimated to be $4,730,000 making a benefit-cost ratio of 1.25 to 1. The estimated power benefits included the increased generation of energy in existing powerplants downstream from Mammoth Pool, but did not include possible power benefits which would result from increasing the dependable capacity of these powerplants.

Recreation, fishery enhancement, and possible conservation benefits were investigated but were not evaluated.

The potential of this project for recreation, fish, and wildlife enhancement, and increased conservation benefits indicates that the project would bejustified with these project purposes included.

TABLE 58

SUMMARY OF ESTIMATED CAPITAL COSTS OF THE PROPOSED UPPER SAN JOAQUIN RIVER PROJECT

(Based on Prices Prevailing in 1965)

Item	Item Cost	Total Cost
Diversion Dams		
Iron Creek	$ 6,900	
North Fork San Joaquin River	687,700	
East Fork Granite Creek	27,500	
Unnamed Granite Creek Tributary	6,900	
West Fork Granite Creek	129,300	
Subtotal, Diversion Dams		$ 858,300
Storage Dams and Reservoirs		
Jackass Meadow	$8,818,000	
Miller Crossing	9,933,000	
Forks	6,319,000	
Chiquito	2,541,000	
Subtotal, Storage Dams and Reservoirs		$27,611,000
Tunnels and Conduits		
Iron Creek-North Fork S.J. River Pipeline	$ 91,200	
North Fork S.J. River to W. Fork Granite Cr. Tunnel and Pipeline	7,061,000	
West Fork Granite Creek-Jackass Meadow Reservoir Tunnel	4,672,000	
Jackass Meadow Res.-Squaw Dome Tunnel and Pipeline	2,957,000	
Miller Crossing Res.-Squaw Dome Tunnel	5,833,000	
Forks Res.-Mammoth Res. Tunnel	6,228,000	
Subtotal, Tunnels and Conduits		$26,842,200

TABLE 58 (Continued)

SUMMARY OF ESTIMATED CAPITAL COSTS OF
THE PROPOSED UPPER SAN JOAQUIN RIVER PROJECT

(Based on Prices Prevailing in 1965)

Item	Item Cost	Total Cost
Powerplants		
Jackass Unit of Squaw Dome Powerplant	$9,333,000	
Miller Unit of Squaw Dome Powerplant	6,372,000	
Forks	6,731,000	
Subtotal, Powerplants		$22,436,000
Penstocks and Penstock Valves		
Jackass Unit of Squaw Dome Powerplant	$4,120,000	
Miller Unit of Squaw Dome Powerplant	791,000	
Forks Powerplant	654,000	
Subtotal, Penstocks and Penstock Valves		$ 5,565,000
Total Capital Cost of Project		$83,312,500

TABLE 59

SUMMARY OF ANNUAL COSTS OF THE
PROPOSED UPPER SAN JOAQUIN RIVER PROJECT

Item	Diversion Dams and Reservoirs	Storage Dams and Reservoirs	Tunnels and Conduits	Powerplants	Penstocks	Total
Interest[1]	$34,000	$1,104,000	$1,074,000	$ 898,000	$223,000	$3,333,000
Repayment[1]	6,000	181,000	176,000	147,000	36,000	546,000
Replacements		1,000		45,000		46,000
Insurance				22,000		22,000
Operation, maintenance and general expense	9,000	54,000	13,000	700,000	7,000	783,000
Total annual costs	$49,000	$1,340,000	$1,263,000	$1,812,000	$266,000	$4,730,000

1/ Based on interest at four percent throughout the 50-year repayment period.

CHAPTER V. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The "Madera Area" encompasses all of Madera County and those portions of the drainage basins of the Chowchilla and Fresno Rivers which lie within Mariposa County. It is an area with striking contrasts -- rich in lumber and soil resources but relatively poor in water resources. It abounds in areas of great recreation potential but lacks development of that potential. It extends from the trough of the great valley of California to the crest of the Sierra Nevada -- ranging from 130 to 13,159 feet above sea level. It encompasses 2,352 square miles but averages less than twenty people for each of these square miles.

There are wide variations in the climate of the Madera area. On the valley floor, temperatures above 100° F are not uncommon in July and August, and along the crest of the Sierra Nevada temperatures plummet to subzero in mid-winter. Mean annual precipitation ranges from less than 10 inches in the Valley to 55 inches along the crest of the Sierra Nevada. Extremes in annual precipitation have ranged from 4.23 inches of rain on the valley floor at Chowchilla Farms (1923-24) to 80 inches of water content in snow at Chilkoot Lake (1951-52). The four-month period from December through March usually produces 70 percent of the precipitation, and the four-month period from June through September brings less than 3 percent. Precipitation each year varies from less than one-half to nearly twice the long-term average.

The economy of the valley floor portion of the Madera area is primarily agricultural. In the foothill and mountainous portions of the area, lumbering, recreation, cattle grazing, and mining constitute the main economic activities. Growth of two of these activities, agriculture and recreation, would be accelerated by the development of water resources. Maintenance of the present degree of irrigated agriculture on the valley floor is possible only through mining of the ground water basin underlying the valley floor in addition to diverting available streamflow and importing via Madera Canal flows of the San Joaquin River conserved in Millerton Lake. Established recreation facilities, such as Bass Lake, are overcrowded and new facilities are badly needed.

A large increase in population in the area is expected as the population in the State as a whole continues to grow. This will require larger quantities of water for both domestic use and increased commercial use. In the foothill and mountainous portions of the area, water for these purposes will probably constitute the largest demands for supplemental supplies.

Two new water development projects have been authorized by Congress for construction by the U. S. Army Corps of Engineers in the Madera area. Hidden Dam and Reservoir would be located on the Fresno River about 13 miles northeast of Madera. The reservoir would impound 90,000 acre-feet of water and would be operated for flood control, water conservation, and recreation. Buchanan Dam, located on the Chowchilla River about 16 miles northeast of the City of Chowchilla, would form a 150,000-acre-foot reservoir. Buchanan would be a multiple-purpose project providing flood control, irrigation, general recreation, and fish and wildlife benefits. If irrigated agriculture continues to increase to the extent projected for the future, additional water supplies may be needed even with the Hidden and Buchanan projects. The feasibility of providing such water should be investigated as soon as possible.

Future water requirements for the upper foothill and mountainous portions of the Madera area cannot be served from authorized and proposed projects of the federal government. Ground water development by individuals, although constituting the major source of supply to these areas at present, is limited in quantity and areal distribution. Some disadvantages of dependence upon wells in these areas include small yields, failures during dry periods, expense of drilling, threat of pollution or contamination, and the risk of drilling a well that produces little or no water. With continued population growth these problems will be intensified.

It would be very difficult and costly for adequate surface water supplies to be developed by individuals. The streams are intermittent and would require carry-over storage from the wet to the dry season. Variations in runoff from year to year may require storage adequate to capture sufficient runoff during wet years to carry over during the dry years which inevitably follow. The threat of pollution and contamination of wells in this area also is present for surface supplies. Solutions of these problems require large investments, usually more than individuals or small groups of individuals can afford.

After reconnaissance-level consideration of alternatives, the Oakhurst-Soquel Project was selected as the most promising for developing water resources in the upper Madera area. The project would provide an adequate water supply, free from the threat of pollution, to all major areas of urban and rural residential growth and would also provide significant recreation and fishery opportunities.

The Upper San Joaquin River Project appears to be justified on the basis of power generation alone and shows, in addition, potential for the inclusion of conservation and recreation. Two of the reservoirs proposed, Chiquito and Jackass Meadow, would have good recreation potentials because of the pleasant summer climate, topographic setting, accessibility, and scenic beauty.

Conclusions

As a result of the Madera Area Investigation the following conclusions have been reached:

1. The construction of the Hidden and Buchanan Projects will only partially alleviate the water deficiency of the Valley Floor Unit of the Madera area.

2. The construction of the East Side Division of the Central Valley Project proposed by the U. S. Bureau of Reclamation appears to be the logical source of supplemental water for the Valley Floor Unit.

3. The present practice of sewage disposal through use of individual septic tanks poses a threat of pollution and/or contamination of local ground and surface waters in the areas within and adjacent to rapidly growing residential areas in the upper Madera area. Future supplemental requirements should be met by large surface water storage projects because of the high costs of individual water supply developments and the imminent pollution problems.

4. The economic demand for supplemental water in the upper Madera area will amount to about 7,600 acre-feet annually by the year 2020. There would probably not be an economic demand for irrigation of significant amounts of agricultural lands.

5. The Madera Irrigation District, riparian water users, and individuals appropriating minor amounts of water under permits and licenses have rights to the first flows of the Fresno River. The cost of developing "new" water by storage reservoirs in the upper Madera area would be very high because water stored during wet years, in many instances, would subsequently have to supply the demands occurring during several consecutive dry years. The most economical means of obtaining water for the upper Madera area would be through exchange

agreements. Supplemental water could be purchased from the U. S. Bureau of Reclamation and furnished to the Madera Irrigation District and other downstream interests. In return a portion of the runoff of the Fresno River could be developed for use in the upstream areas.

6. The Oakhurst-Soquel Project is the most promising means of meeting the water requirements of the upper Madera area. An adequate, dependable supply of potable water could be supplied to all the present and predicted areas of concentrated urban and rural growth more economically than through alternative methods.

7. The Upper San Joaquin River Project would produce several beneficial effects on the economy of the Madera area, including increased numbers of recreationists coming into the area to use project facilities, and increased employment of people required to operate and maintain the project.

Recommendations

It is recommended that:

1. This bulletin be used as a guide for future development of the water resources of the Madera area and that plans be revised as necessary to meet changing patterns of land and water use and economic conditions.

2. The Madera County Board of Supervisors or the appropriate public agency proceed with the development of the Oakhurst-Soquel Project as the next major step in the water resources development of the County.

3. Madera County initiate appropriate higher level studies to determine the timing and size of development of the Upper San Joaquin River Project as a future major project.

4. The feasibility of providing supplemental water for the Valley Floor Unit should be investigated. If it is found that there is an economic demand for additional water, negotiations should be initiated with the Bureau of Reclamation to obtain supplemental water from the East Side Division of the Central Valley Project.

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APPENDIX A

OPERATIONS STUDIES

TABLE A-1

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR[1]
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 1990

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Year Storage	Spill[2]
1914	8,000	12,410	43,274	1,470	0	1,875	832	7,289	10,414
1915	7,289	10,377	29,434	1,470	0	1.875	820	7,289	7,682
1916	7,289	12,288	50,214	1,470	0	1,875	818	7,289	9,595
1917	7,289	10,055	33,563	1,470	26	1,875	820	7,263	7,360
1918	7,263	8,545	21,350	1,470	0	1,875	816	7,289	5,828
1919	7,289	7,272	17,970	1,470	220	1,875	815	6,920	4,751
1920	6,920	7,910	18,062	1,470	97	1,875	806	7,192	4,860
1921	7,192	9,122	23,613	1,470	76	1,875	817	7,213	6,333
1922	7,213	10,225	36,120	1,470	58	1,875	813	7,248	7,444
1923	7,248	10,145	32,186	1,470	0	1,875	818	7,289	7,411
1924	7,289	3,515	8,170	1,470	470	1,875	795	6,413	1,251
1925	6,413	7,951	17,704	1,470	157	1,875	797	7,133	4,402
1926	7,133	6,891	13,640	1,470	298	1,875	807	6,853	4,200

TABLE A-1 (Continued)

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR[1]
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 1990

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Require-ment	Oakhurst-Ahwahnee Release	Other Release	Evapora-tion	End of Year Storage	Spill[2]
1927	6,853	10,208	27,814	1,470	117	1,875	810	7,173	7,086
1928	7,173	6,885	18,828	1,470	299	1,875	813	6,843	4,228
1929	6,843	5,996	10,670	1,470	234	1,875	801	7,041	2,888
1930	7,041	6,010	11,188	1,470	330	1,875	801	6,963	3,082
1931	6,963	3,582	7,105	1,470	434	1,875	785	6.554	897
1932	6,554	10,353	33,531	1,470	98	1,875	801	7,213	6,920
1933	7,213	7,288	13,192	1,470	76	1,875	813	7,213	4,524
1934	7,213	4,694	9,944	1,470	410	1,875	800	6,675	2,147
1935	6,675	9,892	30,448	1,470	66	1,875	805	7,223	6,598
1936	7,223	9,562	33,579	1,470	0	1,875	816	7,289	6,805
1937	7,289	10,333	37,850	1,470	0	1,875	818	7,289	7,640
1938	7,289	14,032	64,818	1,470	0	1,875	822	7,289	11,335
1939	7,289	5,936	13,301	1,470	89	1,875	813	7,022	3,426

TABLE A-1 (Continued)

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR1/
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 1990

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Year Storage	Spill2/
1940	7,022	9,608	30,852	1,470	25	1,875	815	7,264	6,651
1941	7,264	11,651	45,229	1,470	0	1,875	819	7,289	8,932
1942	7,289	11,104	30,841	1,470	0	1,875	823	7,289	8,406
1943	7,289	10,297	31,844	1,470	0	1,875	819	7,289	7,603
1944	7,289	7,760	16,700	1,470	74	1,875	816	7,215	5,069
1945	7,215	10,473	29,715	1,470	16	1,875	819	7,273	7.705
1946	7,273	9,104	19,799	1,470	69	1,875	822	7,220	6,391
1947	7,220	6,689	14,177	1,470	233	1,875	810	6.870	5,741
1948	6,870	6,790	13,773	1,470	147	1,875	802	7,143	3,693
1949	7,143	7,117	13,511	1,470	135	1,875	808	7,063	4,379
1950	7,063	7,700	15,287	1,470	174	1,875	809	7,133	4,772
1951	7,133	8,628	31,850	1,470	112	1,875	821	7,177	5,776
1952	7,177	11,654	42,049	1,470	0	1,875	817	7,289	8,850

TABLE A-1 (Continued)

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR[1/]
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 1990

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Require-ment	Oakhurst-Ahwahnee Release	Other Release	Evapora-tion	End of Year Storage	Spill[2/]
1953	7,289	7,163	15,487	1,470	172	1,875	815	7,118	4,472
1954	7,118	7,425	14,560	1,470	214	1,875	808	7,061	4,585
1955	7,061	6,675	12,846	1,470	224	1,875	807	7,094	3,736
1956	7,094	11,007	44,073	1,470	43	1,875	817	7,273	8,093
1957	7,273	7,080	13,647	1,470	155	1,875	815	7,135	4,373
1958	7,135	11,153	39,424	1,470	0	1,875	815	7,289	8,309
1959	7,289	6,443	12,551	1,470	157	1,875	810	6,956	3,934
1960	6,956	5,895	13,360	1,470	195	1,875	801	6.926	3,054
1961	6,926	4,402	8,329	1,470	353	1,875	795	6,703	1.602
1962	6,703	9,645	20,595	1,470	33	1,875	800	7.289	6,351
1963	7,289	9,125	29,026	1,470	0	1,875	818	7,289	6,432

1/ Normal pool = 8,000 acre-feet; minimum pool = 3,000 acre-feet.
Note: Critical dry period was between June 1924 and April 1925 during which a maximum drawdown of 1,695 acre-feet occurred in October 1924.

2/ This "spill" includes only water available from "Soquel Diversion".

TABLE A-2

MONTHLY OPERATION STUDY OF SOQUEL RESERVOIR[1] DURING CRITICAL DRY PERIOD UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 1990

(in Acre-feet)

Year	Month	First of Month Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Month Storage	Spill[2] (- Equals space)
1923	Oct.	7289	155	1810	117	0	150	69	7225	-774
	Nov.	7225	145	351	102	0	131	35	7204	-796
	Dec.	7204	130	561	88	0	113	25	7195	-804
1924	Jan.	7195	145	760	88	0	112	16	7211	-788
	Feb.	7211	200	840	88	0	112	18	7280	-719
	March	7280	400	1562	88	0	113	31	7536	-463
	April	7536	1040	1101	88	0	112	50	8000	414
	May	8000	1060	965	117	0	150	79	8000	830
	June	8000	200	140	147	7	188	104	7900	-99
	July	7900	40	40	176	136	225	145	7433	-566
	Aug.	7433	0	20	191	171	244	128	6890	-1109
	Sept.	6890	0	20	176	156	225	95	6413	-1586

TABLE A-2 (Continued)

MONTHLY OPERATION STUDY OF SOQUEL RESERVOIR[1] DURING CRITICAL DRY PERIOD UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 1990

(in Acre-feet)

Year	Month	First of Month Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Month Storage	Spill[2] (- Equals space)
1924	Oct.	6413	103	150	117	0	150	62	6304	-1695
	Nov.	6304	190	662	102	0	131	31	6331	-1668
	Dec.	6331	180	656	88	0	113	23	6375	-1624
1925	Jan.	6375	190	702	88	0	112	14	6438	-1561
	Feb.	6438	318	3655	88	0	112	17	6626	-1373
	March	6626	1050	2504	88	0	113	30	7533	-466
	April	7533	1800	3550	88	0	112	50	8000	1171
	May	8000	2340	3254	117	0	150	79	8000	2110
	June	8000	1380	2041	147	0	188	104	8000	1087
	July	8000	400	320	176	0	225	148	8000	26
	Aug.	8000	0	140	191	51	244	136	7568	-431
	Sept.	7568	0	70	176	106	225	103	7133	-866

1/ Normal pool = 8,000 acre-feet; minimum pool = 3,000 acre-feet.
Note: Critical dry period was between July 1930 and May 1932 during which a maximum drawdown of 5,163 acre-feet occurred in November 1931.

2/ This "spill" includes only water available from "Soquel Diversion".

TABLE A-3

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR[1/]
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Year Storage	Spill[2/]
1914	8,000	15,829	39,843	3,745	216	3,840	824	7,065	11,885
1915	7,065	13,048	26,751	3,745	0	3,840	808	6,959	8,506
1916	6,959	15,426	47,064	3,745	227	3,840	803	6,968	10,547
1917	6,968	12,821	30,785	3,745	338	3,840	809	6,604	8,198
1918	6,604	10,638	19,212	3,745	933	3,840	775	6,309	5,385
1919	6,309	9,228	15,993	3,745	1,146	3,840	759	5,382	4,410
1920	5,382	9,852	16,108	3,745	1,025	3,840	737	6,084	3,548
1921	6,084	11,546	20,477	3,745	714	3,840	780	6,175	6,121
1922	6,175	12,937	33,397	3,745	1,027	3,840	761	6,288	7,196
1923	6,288	13,147	29,171	3,745	189	3,840	792	7,228	7,386
1924	7,228	4,487	7,186	3,745	1,596	3,840	738	4,470	1,071
1925	4,470	9,994	15,649	3,745	1,182	3,840	713	5,757	2,972
1926	5,757	8,448	12,071	3,745	1,375	3,840	733	5,315	2,942

TABLE A-3 (Continued)

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR[1]
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Year Storage	Spill[2]
1927	5,315	12,859	25,152	3,745	976	3,840	753	6,126	6,479
1928	6,126	8,799	16,902	3,745	1,205	3,840	757	5,304	3,819
1929	5,304	7,454	9,200	3,745	1,315	3,840	709	5,572	1,322
1930	5,572	7,438	9,748	3,745	1,716	3,840	709	5,447	1,298
1931	5,447	4,468	6,202	3,745	1,803	3,840	607	3,665	0
1932	3,665	13,123	30,744	3,745	1,020	3,840	702	6,302	4,924
1933	6,302	9,087	11,381	3,745	1,188	3,840	762	6,131	3.468
1934	6,131	5,946	8,680	3,745	1,745	3,840	723	5,123	646
1935	5,123	12,359	27,969	3,745	585	3,840	751	6,513	5,793
1936	6,513	11,945	31,184	3,745	123	3,840	791	6,765	6,939
1937	6,765	13,021	35,150	3,745	38	3,840	798	6,874	8,236
1938	6,874	17,989	60,850	3,745	49	3,840	807	7,065	13,102
1939	7,065	7,466	11,759	3,745	726	3,840	775	5,774	3,416

TABLE A-3 (Continued)

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR[1/]
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Year Storage	Spill[2/]
1940	5,774	12,099	23,740	3,745	679	3,840	767	6,138	6,449
1941	6,138	14,965	39,902	3,745	68	3,840	790	6,979	9,426
1942	6,979	14,119	27,814	3,745	0	3,840	810	6,938	9,510
1943	6,938	13,024	29,105	3,745	0	3,840	807	6,904	8,411
1944	6,904	9,767	14,681	3,745	743	3,840	790	6,196	5,102
1945	6,196	13,393	26,783	3,745	675	3,840	785	6,480	7,806
1946	6,480	11,606	17,385	3,745	807	3,840	791	6,089	6,559
1947	6,089	8,618	12,236	3,745	1,156	3,840	752	5,331	3,628
1948	5,331	8,438	12,113	3,745	1,136	3,840	721	5,888	2,184
1949	5,888	8,775	11,842	3,745	1,432	3,840	729	5,563	3,099
1950	5,563	9,592	13,383	3,745	1,353	3,840	735	5,706	3,521
1951	5,706	11,433	29,033	3,745	1,037	3,840	776	6,011	5,475
1952	6,011	14,925	41,768	3,745	188	3,840	781	6,990	9,137

TABLE A-3 (Continued)

ANNUAL SUMMARY OF OPERATION STUDY OF SOQUEL MEADOW RESERVOIR 1/
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Water Year	First of Year Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Require-ment	Oakhurst-Ahwahnee Release	Other Release	Evapora-tion	End of Year Storage	Spill 2/
1953	6,990	9,020	13,618	3,745	849	3,840	791	6,071	4,459
1954	6,071	9,187	12,787	3,745	1,321	3,840	747	5,617	3,733
1955	5,617	8,406	11,103	3,745	1,317	3,840	731	5,727	2,408
1956	5,727	14,262	40,806	3,745	803	3,840	773	6,508	8,065
1957	6,508	8,927	11,788	3,745	865	3,840	778	6,028	3,924
1958	6,028	14,164	36,382	3,745	250	3,840	775	6,974	8,353
1959	6,974	8,170	10,812	3,745	825	3,840	769	5,768	3,942
1960	5,768	7,317	10,829	3,745	1,447	3,840	725	5,493	1,580
1961	5,493	5,586	7,133	3,745	1,350	3,840	713	5,165	11
1962	5,165	11,865	18,363	3,745	792	3,840	736	6,370	5,292
1963	6,370	11,729	26,411	3,745	186	3,840	789	6,718	6,566

1/ Normal pool = 8,000 acre-feet; minimum pool = 3,000 acre-feet.
Note: Critical dry period was between July 1930 and May 1932 during which a maximum drawdown of 5,163 acre-feet occurred in November 1931.

2/ This "spill" includes only water available from "Soquel Diversion".

MONTHLY OPERATION STUDY OF SOQUEL RESERVOIR[1/] DURING CRITICAL DRY PERIOD UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Year	Month	First of Month Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Month Storage	Spill (- Equals space)
1929	Oct.	5572	61	33	299	266	307	53	5007	-2992
	Nov.	5007	86	58	262	203	269	25	4596	-3404
	Dec.	4596	101	118	224	106	230	17	4343	-3656
1930	Jan.	4343	168	1686	224	0	230	10	4271	-3728
	Feb.	4271	282	1440	224	0	230	12	4311	-3688
	March	4311	1045	3058	224	0	230	21	5105	-2894
	April	5105	1638	1085	224	0	230	39	6475	-1524
	May	6475	2060	1240	299	0	307	73	8000	155
	June	8000	1631	788	374	0	385	104	8000	1141
	July	8000	332	147	449	302	461	145	7424	-575
	Aug.	7424	26	73	486	413	500	124	6413	-1586
	Sept.	6413	8	22	449	426	461	86	5447	-2552
	Oct.	5447	104	73	299	225	307	52	4966	-3033

TABLE A-4 (Continued)

MONTHLY OPERATION STUDY OF SOQUEL RESERVOIR[1/] DURING CRITICAL DRY PERIOD
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Year	Month	First of Month Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Require-ment	Oakhurst-Ahwahnee Release	Other Release	Evapora-tion	End of Month Storage	Spill (- Equals space)
1930	Nov.	4966	137	134	262	127	269	25	4681	-3318
	Dec.	4681	102	227	224	0	230	17	4536	-3463
1931	Jan.	4536	136	1638	224	0	230	11	4431	-3568
	Feb.	4431	194	976	224	0	230	12	4383	-3616
	March	4383	535	1028	224	0	230	20	4668	-3331
	April	4668	1076	837	224	0	230	35	5479	-2520
	May	5479	1641	985	299	0	307	63	6750	-1249
	June	6750	476	213	374	160	385	90	6590	-1409
	July	6590	51	32	449	416	461	120	5643	-2356
	Aug.	5643	13	36	486	450	500	97	4609	-3390
	Sept.	4609	8	23	449	425	461	65	3665	-4334
	Oct.	3665	84	70	299	229	307	38	3176	-4824

TABLE A-4 (Continued)

MONTHLY OPERATION STUDY OF SOQUEL RESERVOIR[1/] DURING CRITICAL DRY PERIOD
UNDER DEMANDS ESTIMATED TO OCCUR IN YEAR 2020

(in Acre-feet)

Year	Month	First of Month Storage	Soquel Reservoir Inflow	Flow in Lewis Fork	Oakhurst-Ahwahnee Requirement	Oakhurst-Ahwahnee Release	Other Release	Evaporation	End of Month Storage	Spill (- Equals space)
1931	Nov.	3176	121	88	262	173	269	17	2836	-5163
	Dec.	2836	468	6071	224	0	230	12	3062	-4937
1932	Jan.	3062	387	5261	224	0	230	8	3211	-4788
	Feb.	3211	747	8877	224	0	230	10	3719	-4280
	March	3719	1762	2848	224	0	230	20	5231	-2768
	April	5231	2152	1710	224	0	230	41	7112	-887
	May	7112	3381	2872	299	0	307	75	8000	2111
	June	8000	2745	2041	374	0	385	104	8000	2255
	July	800C	1164	590	449	0	461	148	8000	555
	Aug.	8000	86	243	486	243	500	133	7209	-790
	Sept.	7209	26	73	449	375	461	96	6302	-1697

1/ Normal pool = 8,000 acre-feet; minimum pool = 3,000 acre-feet.

TABLE A-5

PROPOSED OPERATION OF JACKASS MEADOW RESERVOIR
DURING CRITICAL DRY PERIOD 1927-28 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Fish Release	Water Releases and Losses: Power Release: Primary	Power Release: Secondary	Evaporation	Spill	Storage End of Month
1927	Oct.	2,030	600	8,056		216		56,219
	Nov.	8,220	600	6,848		113		56,878
	Dec.	2,700	600	7,250		79		51,649
1928	Jan.	2,450	600	6,445		46		47,008
	Feb.	3,010	600	5,639		44		43,735
	March	13,250	600	7,250		74		49,061
	April	23,900	600	8,056		146		63,959
	May	55,440	600	8,480	15,037	282		95,000
	June	19,680	600	10,886	7,810	384		95,000
	July	5,200	300	13,706		517		85,677
	Aug.	1,510	300	13,706		470		72,711
	Sept.	680	300	9,678		352		63,061
TOTALS		137,870	6,300	106,000	22,847	2,723		
1928	Oct.	975	300	8,056		216		55,464
	Nov.	977	300	6,848		109		49,184
	Dec.	897	300	7,250		73		42.458
1929	Jan.	860	300	6,445		41		36,532
	Feb.	1,048	300	5,639		36		31,605
	March	5,921	300	7,250		56		29,920
	April	14,113	300	8,056		108		35,569
	May	45,183	300	8,480		234		71,738
	June	28,886	300	10,886		357		89,081
	July	10,421	300	13,706		510		84,986
	Aug.	2,265	300	13,706		470		72,775
	Sept.	809	300	9,678		352		63,254
TOTALS		112,355	3,600	106,000		2,562		
1929	Oct.	671	300	8,056		216		55,353
	Nov.	638	300	6,848		109		48,734
	Dec.	566	300	7,250		73		41,677
1930	Jan.	949	300	6,445		40		35,891
	Feb.	1,665	300	5,639		36		31,581
	March	7,667	300	7,250		56		31,642
	April	22,076	300	8,056		122		45,240
	May	31,730	300	8,480		243		67,947
	June	37,648	300	10,886		358		94,051
	July	8,617	300	13,706		517		88,145
	Aug.	2,120	300	13,706		470		75,780
	Sept.	890	300	9,678		358		66,343
TOTALS		115,287	3,600	106,000		2,598		

TABLE A-5 (Continued)

PROPOSED OPERATION OF JACKASS MEADOW RESERVOIR
DURING CRITICAL DRY PERIOD 1927-28 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Water Releases and Losses: Fish Release	Power Release: Primary	Power Release: Secondary	Evaporation	Spill	Storage End of Month
1930	Oct.	1,549	300	8,056		221		59,315
	Nov.	1,566	300	6,848		122		53,611
	Dec.	778	300	7,250		76		46,763
1931	Jan.	1,018	300	6,445		43		40,993
	Feb.	1,245	300	5,639		41		36,258
	March	4,117	300	7,250		60		32,765
	April	14,846	300	8,056		108		39,147
	May	29,020	300	8,480		328		59,159
	June	11,089	300	10,886		315		58,747
	July	2,999	300	13,706		408		47,332
	Aug.	2,035	300	13,706		350		35,011
	Sept.	1,343	300	9,678		224		26,152
TOTALS		71,605	3,600	106,000		2,196		
1931	Oct.	631	300	8,056		133		18,294
	Nov.	715	300	6,848		57		11,804
	Dec.	3,981	300	7,250		30		8,205
1932	Jan.	2,899	300	6,445		10		4,349
	Feb.	7,171	600	5,639		7		5,274
	March	11,044	600	7,250		22		8,446
	April	29,528	600	8,056	15,984	83		13,251
	May	66,537	600	8,480	15,560	180		54,968
	June	73,172	600	10,886	13,154	357	8,143	95,000
	July	27,558	600	13,706	10,334	525	2,393	95,000
	Aug.	4,646	600	13,706		498		84,842
	Sept.	1,405	600	9,678		376		75,593
TOTALS		229,287	6,000	106,000	55,032	2,278	10,536	

TABLE A-6

PROPOSED OPERATION OF MILLER CROSSING RESERVOIR
DURING CRITICAL DRY PERIOD 1927-28 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Water Releases and Losses: Fish Release	Power Release: Primary	Power Release: Secondary	Evaporation	Spill	Storage End of Month
1927	Oct.	5,300	1,200	10,108		39		33,953
	Nov.	12,600	1,200	8,592	6,741	20		30,000
	Dec.	7,160	1,200	9,097	6,850	13		20,000
1928	Jan.	6,720	1,200	8,086	2,428	6		15,000
	Feb.	7,850	1,200	7,076	4,568	6		10,000
	March	30,560	1,200	9,097	25,252	11		5,000
	April	40,100	1,200	10,108	28,773	19		5,000
	May	93,880	1,200	10,640	23,998	42		63,000
	June	40,080	1,200	13,659	25,135	86		63,000
	July	13,260	600	17,197		114		58,349
	Aug.	6,300	600	17,197		99		46,753
	Sept.	3,520	600	12,143		66		37,464
TOTALS		267,330	12,600	133,000	123,745	521		
1928	Oct.	2,442	600	10,108		36		29,162
	Nov.	2,262	600	8,592		17		22,215
	Dec.	2,714	600	9,097		11		15,221
1929	Jan.	2,902	600	8,086		5		9,432
	Feb.	3,512	600	7,076		4		5,264
	March	13,180	1,200	9,097	3,140	7		5,000
	April	24,896	1,200	10,108	13,573	15		5,000
	May	76,512	1,200	10,640	24,630	42		45,000
	June	56,578	1,200	13,659	23,642	77		63,000
	July	20,886	1,200	17,197	2,372	117		63,000
	Aug.	3,110	1,200	17,197		103		47,610
	Sept.	1,535	1,200	12,143		65		35,737
TOTALS		210,529	11,400	133,000	67,357	499		
1929	Oct.	1,473	600	10,108		35		26,467
	Nov.	1,402	600	8,592		16		18,661
	Dec.	1,565	600	9,097		9		10,520
1930	Jan.	3,382	600	8,086		4		5,212
	Feb.	5,557	600	7,076		3		3,090
	March	16,506	1,200	9,097	4,293	6		5,000
	April	38,791	1,200	10,108	27,464	19		5,000
	May	53,734	1,200	10,640	18,857	37		28,000
	June	66,652	1,200	13,659	16,726	67		63,000
	July	17,206	600	17,197		117		62,292
	Aug.	4,702	600	17,197		103		49,094
	Sept.	1,776	600	12,143		7		38,120
TOTALS		212,746	9,600	133,000	67,340	423		

TABLE A-6 (Continued)

PROPOSED OPERATION OF MILLER CROSSING RESERVOIR
DURING CRITICAL DRY PERIOD 1927-28 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Fish Release	Water Releases and Losses: Power Release: Primary	Power Release: Secondary	Evaporation	Spill	Storage End of Month
1930	Oct.	3,346	600	10,108		36		30,722
	Nov.	3,226	600	8,592		18		24,738
	Dec.	2,126	600	9,097		11		17,156
1931	Jan.	3,256	600	8,086		6		11,720
	Feb.	4,031	600	7,076		5		8,070
	March	8,520	600	9,097		7		6,886
	April	24,630	600	10,108		17		20,791
	May	45,937	600	10,640		47		55,441
	June	17,111	600	13,659		80		58,213
	July	4,711	600	17,197		101		45,026
	Aug.	3,195	600	17,197		76		30,348
	Sept.	2,277	600	12,143		48		19,834
TOTALS		122,366	7,200	133,000		452		
1931	Oct.	1,542	600	10,108		25		10,643
	Nov.	1,685	600	8,592		10		3,126
	Dec.	12,030	600	9,097		6		5,453
1932	Jan.	9,628	600	8,086		4		6,391
	Feb.	23,196	1,200	7,076	11,305	6		10,000
	March	29,702	1,200	9,097	24,394	11		5,000
	April	51,767	1,200	10,108	40,437	22		5,000
	May	112,551	1,200	10,640	44,360	42	38,309	23,000
	June	133,668	1,200	13,659	41,341	65	37,403	63,000
	July	60,386	1,200	17,197	37,803	117	4,069	63,000
	Aug.	12,713	1,200	17,197		110		57,206
	Sept.	3,891	1,200	12,143		78		47,676
TOTALS		452,759	12,000	133,000	199,640	496	79,781	

TABLE A-7

PROPOSED OPERATION OF FORKS RESERVOIR
DURING CRITICAL DRY PERIOD 1927-28 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Water Releases and Losses: Fish Release	Power Release: Primary	Power Release: Secondary	Evaporation	Spill	Storage End of Month
1927	Oct.	22,344	1,800	20,520		71		19,953
	Nov.	31,661	1,800	17,442	3,829	43		28,500
	Dec.	27,987	1,800	18,468	7,681	38		28,500
1928	Jan.	21,739	1,800	16,416	3,500	23		28,500
	Feb.	22,813	1,800	14,364	18,123	26		17,000
	March	59,509	1,800	18,468	51,200	41		5,000
	April	63,637	1,800	20,520	41,264	53		5,000
	May	81,875	1,800	21,600	43,392	83		20,000
	June	77,640	1,800	27,729	39,484	127		28,500
	July	32,823	1,800	34,911		182		24,430
	Aug.	31,883	1,800	34,911		166		19,436
	Sept.	22,731	1,800	24,651		117		15,599
TOTALS		496,642	21,600	270,000	208,473	970		
1928	Oct.	19,274	1,800	20,520		67		12,486
	Nov.	17,520	1,800	17,442		31		10,733
	Dec.	19,047	1,800	18,468		21		9,491
1929	Jan.	17,201	1,800	16,416		12		8,464
	Feb.	16,325	1,800	14,364		13		8,612
	March	26,907	1,800	18,468	10,224	27		5,000
	April	41,457	1,800	20,520	19,075	62		5,000
	May	65,210	1,800	21,600	22,761	49		24,000
	June	55,207	1,800	27,729	21,044	134		28,500
	July	33,825	1,800	34,911		184		25,430
	Aug.	32,873	1,800	34,911		166		21,426
	Sept.	24,441	1,800	24,651		129		19,287
TOTALS		369,287	21,600	270,000	73,104	895		
1929	Oct.	19,694	1,800	20,520		64		16,597
	Nov.	16,870	1,800	17,442		36		14,189
	Dec.	18,617	1,800	18,468		26		12,512
1930	Jan.	17,601	1,800	16,416		15		11,882
	Feb.	18,395	1,800	14,364		17		14,096
	March	30,490	1,800	18,468	19,284	34		5,000
	April	62,378	1,800	20,520	39,969	89		5,000
	May	52,147	1,800	21,600	13,664	83		20,000
	June	52,981	1,800	27,729	14,825	127		28,500
	July	32,323	900	34,911		181		24,831
	Aug.	32,103	900	34,911		166		20,957
	Sept.	23,351	900	24,651		122		18,635
TOTALS		376,950	18,900	270,000	87,742	960		

TABLE A-7 (Continued)

PROPOSED OPERATION OF FORKS RESERVOIR
DURING CRITICAL DRY PERIOD 1927-28 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Fish Release	Power Release: Primary	Power Release: Secondary	Evaporation	Spill	Storage End of Month
1930	Oct.	19,134	900	20,520		76		16,273
	Nov.	17,210	900	17,442		36		15,105
	Dec.	18,247	900	18,468		29		13,955
1931	Jan.	17,101	900	16,416		16		13,724
	Feb.	16,235	900	14,364		19		14,676
	March	22,117	900	18,468		32		17,393
	April	27,754	900	20,520		55		23,672
	May	23,670	900	21,600		95		24,747
	June	22,935	900	27,729		122		18,931
	July	31,213	900	34,911		150		14,183
	Aug.	31,153	900	34,911		113		9,412
	Sept.	22,491	900	24,651		131		6,221
TOTALS		269,260	10,800	270,000		874		
1931	Oct.	19,234	900	20,520		29		4,006
	Nov.	16,810	900	17,442		12		2,462
	Dec.	19,437	900	18,468		8		2,523
1932	Jan.	18,991	900	16,416		5		4,193
	Feb.	35,460	1,800	14,364	14,470	19		9,000
	March	58,961	1,800	18,468	42,652	41		5,000
	April	102,776	1,800	20,520	53,480	53	26,923	5,000
	May	165,206	1,800	21,600	52,400	83	88,323	6,000
	June	192,558	1,800	27,729	46,271	110	94,148	28,500
	July	119,002	1,800	34,911	39,089	189	43,013	28,500
	Aug.	34,423	1,800	34,911		179		26,033
	Sept.	24,411	1,800	24,651		138		23,855
TOTALS		807,269	18,000	270,000	248,362	866	252,407	

TABLE A-8

PROPOSED OPERATION OF CHIQUITO RESERVOIR
DURING CRITICAL DRY PERIOD 1929-30 THROUGH 1931-32

(in Acre-feet)

Year	Month	Estimated Inflow	Water Releases and Losses: Fish Release	Release to Mammoth Pool	Evaporation	Spill	Storage End of Month
1929	Oct.	185	600	6,000	55		27,725
	Nov.	285	600	6,000	27		21,383
	Dec.	336	600	6,000	14		15,105
1930	Jan.	667	600	6,000	5		9,167
	Feb.	1,427	600		6		9,988
	March	4,426	600		9		13,805
	April	9,230	600		23		22,412
	May	9,042	600		60		30,794
	June	6,162	600	1,266	90		35,000
	July	865	600	135	130		35,000
	Aug.	428	600		124		34,704
	Sept.	147	600		98		34,153
TOTALS		33,200	7,200	25,401	641		
1930	Oct.	334	600	6,000	56		27,831
	Nov.	524	600	6,000	28		21,727
	Dec.	352	600	6,000	14		15,465
1931	Jan.	496	600	6,000	5		9,356
	Feb.	799	600		6		9,549
	March	1,829	600		9		10,769
	April	4,759	600		18		14,910
	May	6,242	300		41		20,811
	June	1,282	300		61		21,732
	July	194	300		86		21,540
	Aug.	238	300		82		21,396
	Sept.	151	300		65		21,182
TOTALS		17,200	5,700	24,000	471		
1931	Oct.	246	300	6,000	35		15,093
	Nov.	435	300	6,000	15		9,213
	Dec.	3,280	300	6,000	7		6,186
1932	Jan.	2,427	300	6,000	3		2,310
	Feb.	7,586	600		5		9,291
	March	9,762	600	13,446	7		5,000
	April	15,004	600	6,000	14		13,390
	May	23,458	600	1,193	55		35,000
	June	15,494	600	14,801	93		35,000
	July	3,831	600	3,101	130		35,000
	Aug.	1,467	600	743	124		35,000
	Sept.	410	600		99		34,711
TOTALS		83,400	6,000	63,284	587		

TABLE A-9

ESTIMATED ANNUAL ENERGY PRODUCTION OF THE PROPOSED
UPPER SAN JOAQUIN RIVER PROJECT
DURING AVERAGE PERIOD 1907-08 THROUGH 1956-57

(in Millions of Kilowatt-hours)

	Squaw Dome Power Plant		Forks	
Water Year	Jackass Unit	Miller Unit	Power Plant	Total
1907-08	321	158	244	723
09	538	227	341	1106
10	469	214	304	987
1910-11	553	232	348	1133
12	292	145	225	662
13	269	127	195	591
14	518	227	336	1081
15	474	212	300	986
16	518	225	332	1075
17	472	212	297	981
18	388	190	259	837
19	353	176	241	770
20	355	179	244	778
1920-21	416	199	273	888
22	515	223	326	1064
23	426	200	276	902
24	269	91	142	502
25	269	173	218	660
26	318	152	244	714
27	462	214	305	981
28	312	151	234	697
29	269	126	192	587
30	269	126	197	592
1930-31	269	91	142	502
32	282	193	281	756
33	307	153	237	697
34	269	108	154	531
35	406	211	297	914
36	461	209	292	962
37	548	218	313	1079
38	556	232	350	1138
39	269	132	202	603
40	458	210	294	962
1940-41	530	225	329	1084
42	507	219	315	1041
43	490	214	305	1009
44	507	171	238	916
45	495	216	310	1021
46	436	205	283	924
47	310	154	246	710
48	331	163	226	720
49	322	158	242	722
50	353	177	243	773

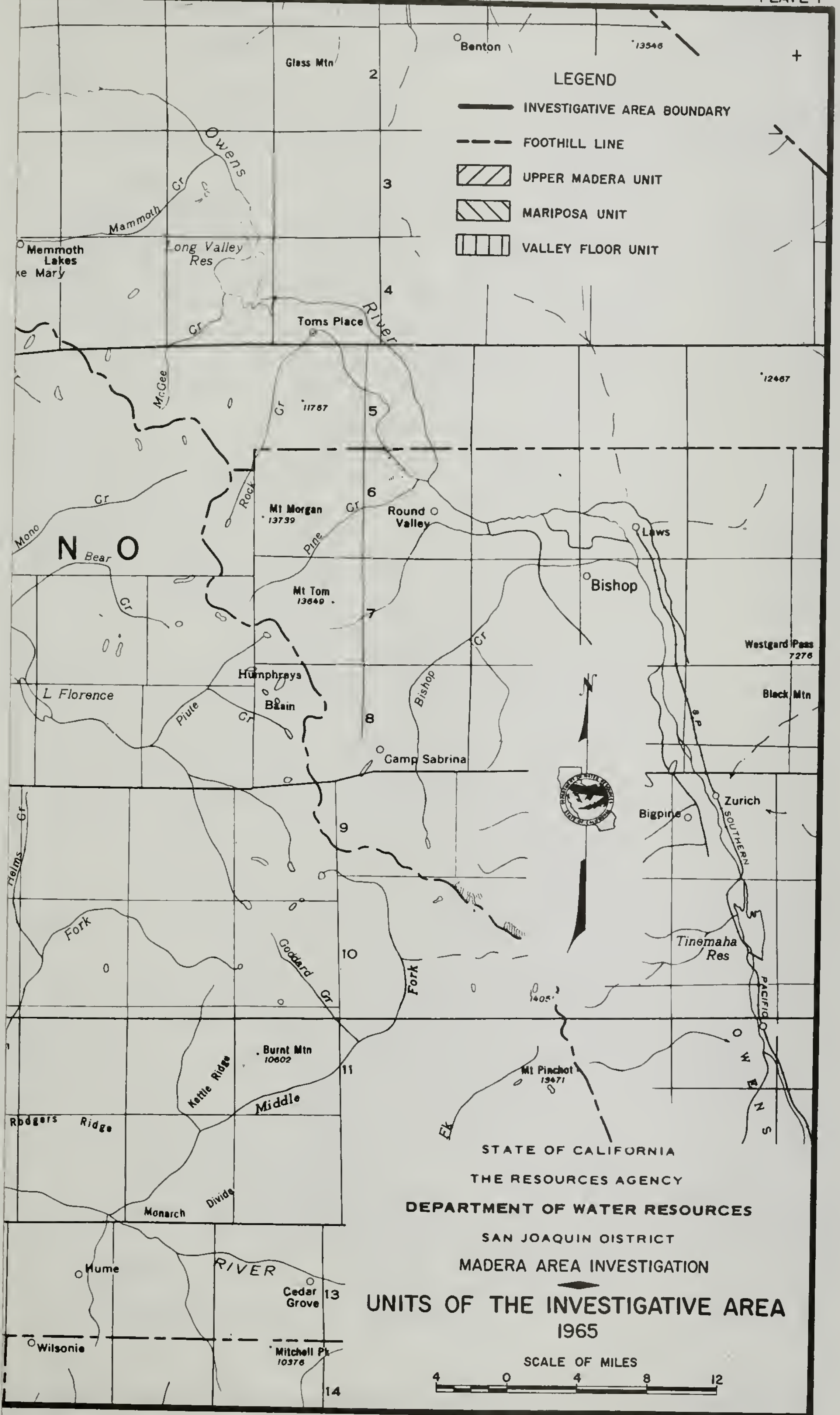
TABLE A-9 (Continued)

ESTIMATED ANNUAL ENERGY PRODUCTION OF THE PROPOSED
UPPER SAN JOAQUIN RIVER PROJECT
DURING AVERAGE PERIOD 1907-08 THROUGH 1956-57

(in Millions of Kilowatt-hours)

Water Year	Squaw Dome Power Plant: Jackass Unit	Squaw Dome Power Plant: Miller Unit	Forks Power Plant	Total
1950-51	459	209	293	961
52	543	225	331	1099
53	335	166	238	739
54	337	180	246	763
55	299	164	233	696
56	538	226	334	1098
57	353	195	265	813
Totals	20,015	9,203	13,312	42,530
50-Year Average	401	184	266	851

PLATE I



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

UNITS OF THE INVESTIGATIVE AREA
1965

SCALE OF MILES
4 0 4 8 12

TABLE A-9 (Continued)

ESTIMATED ANNUAL ENERGY PRODUCTION OF THE PROPOSED
UPPER SAN JOAQUIN RIVER PROJECT
DURING AVERAGE PERIOD 1907-08 THROUGH 1956-57

(in Millions of Kilowatt-hours)

Water Year	Squaw Dome Power Plant		Forks Power Plant	Total
	Jackass Unit	Miller Unit		
1950-51	459	209	293	961
52	543	225	331	1099
53	335	166	238	739
54	337	180	246	763
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56	538	226	334	1098
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Totals	20,015	9,203	13,312	42,530
50-Year Average	401	184	266	851

PLATE I

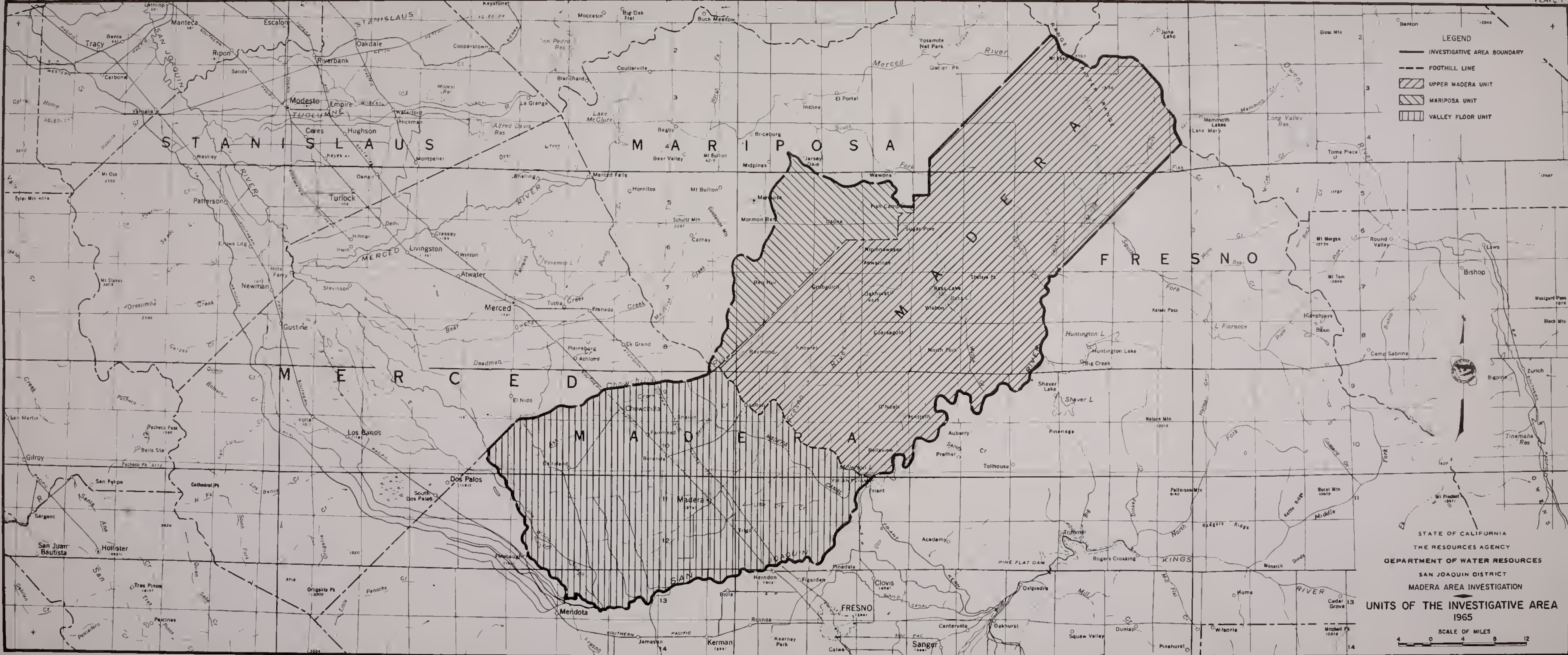
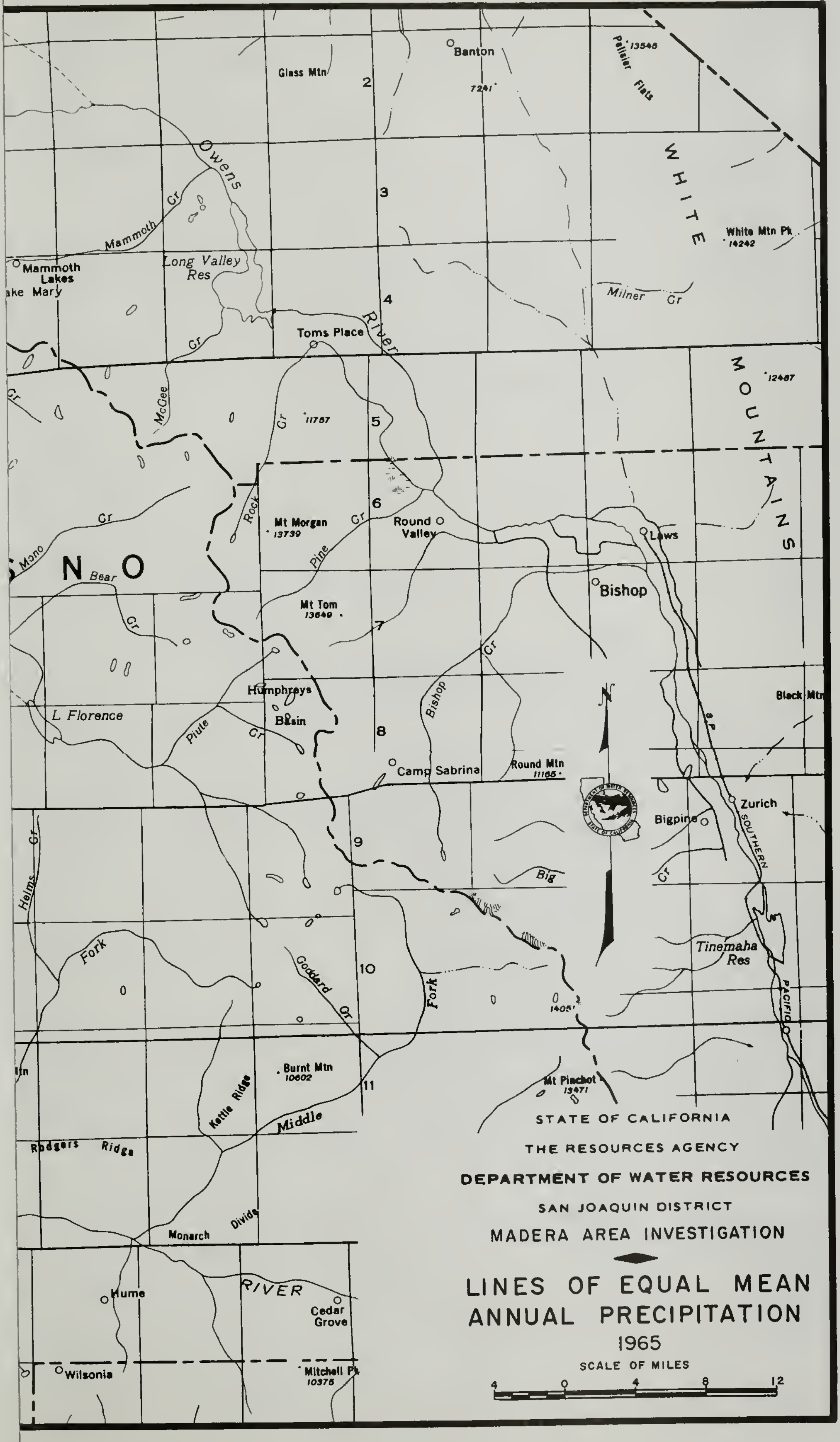

LEGEND
INVESTIGATIVE AREA BOUNDARY
FOOTHILL LINE
UPPER MADERA UNIT
MARIPOSA UNIT
VALLEY FLOOR UNIT
STANISLAUS
MARIPOSA
MADERA
MERCED
MADERA
FRESNO
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
UNITS OF THE INVESTIGATIVE AREA
1965
SCALE OF MILES
4 0 4 8 12

PLATE 2



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

LINES OF EQUAL MEAN ANNUAL PRECIPITATION
1965


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
LINES OF EQUAL MEAN ANNUAL PRECIPITATION
1965
SCALE OF MILES
STANISLAUS
MARIPOSA
MERCED
MADERA
FRESNO
WHITE MOUNTAINS
Tracy
Manteca
Escalon
Oakdale
Riverbank
Modesto
Empire
Ripon
Ceres
Hughson
Turlock
Patterson
Newman
Gustine
Livingston
Atwater
Merced
Le Grand
Chowchilla
Madera
Los Banos
Dos Palos
Mendota
Firebaugh
Kerman
FRESNO
Clovis
Sanger
Hollister
Gilroy
San Juan Bautista
Mariposa
Oakhurst
Coarsegold
North Fork
Bass Lake
Wawona
Yosemite Nat Park
El Portal
Coulterville
Bishop
Benton
Shaver Lake
Huntington Lake
Millerton L
Friant
SAN JOAQUIN
KINGS
RIVER
Merced
Chowchilla
Fresno
Owens
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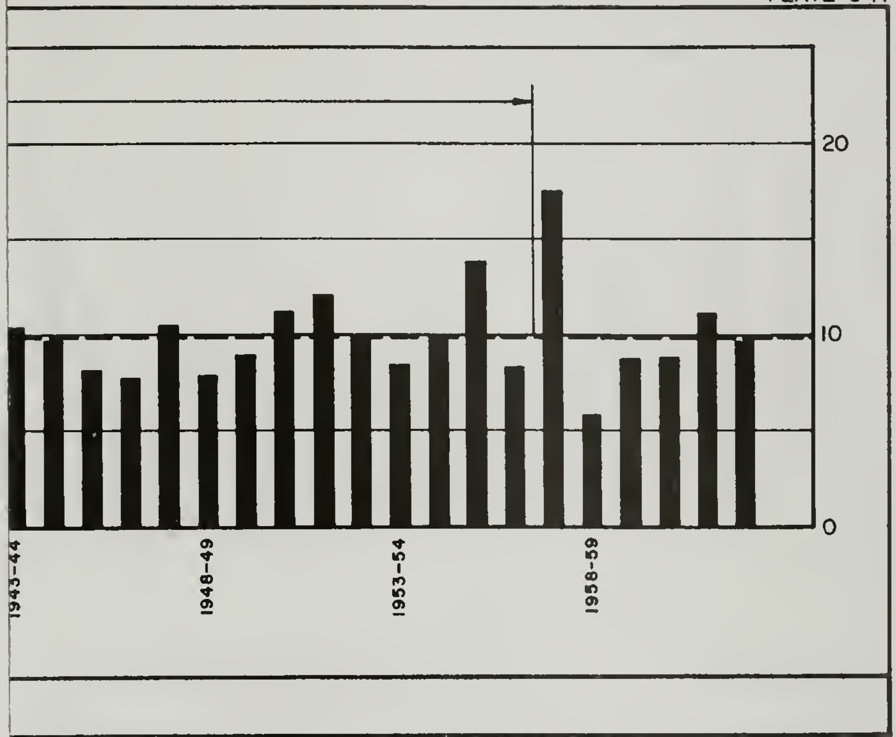
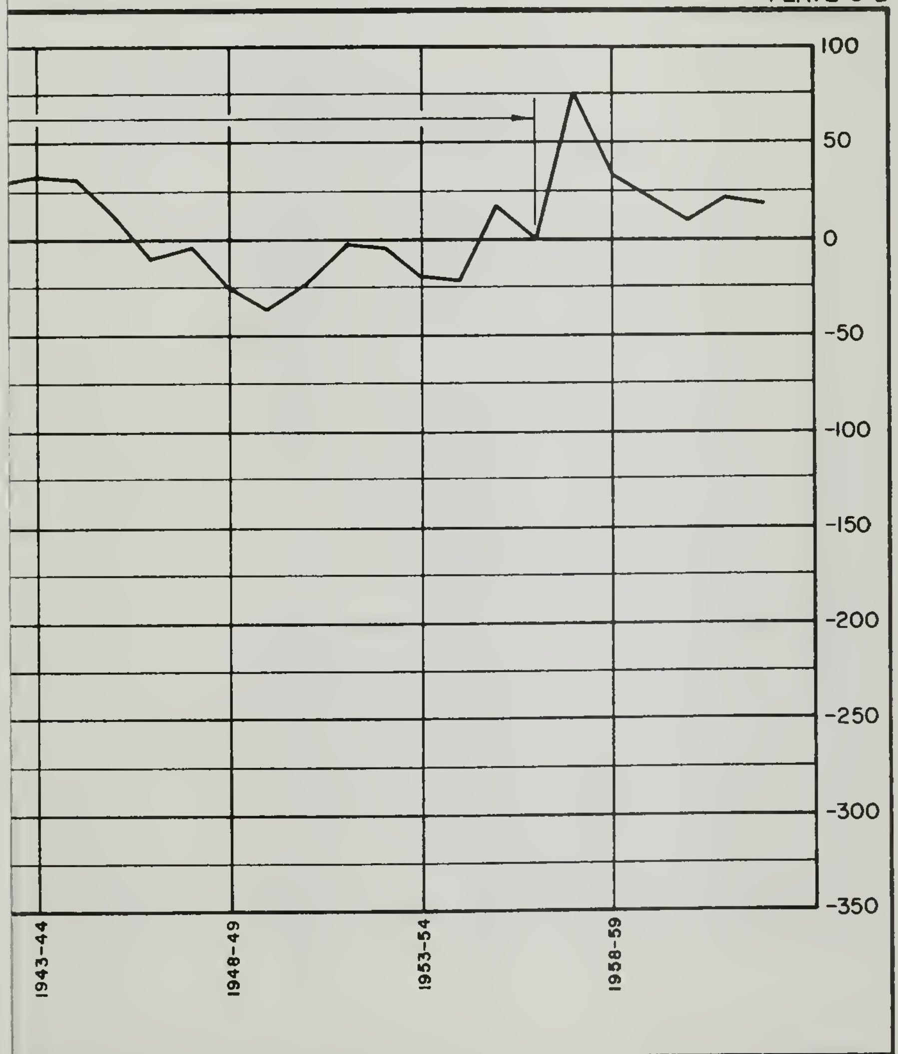
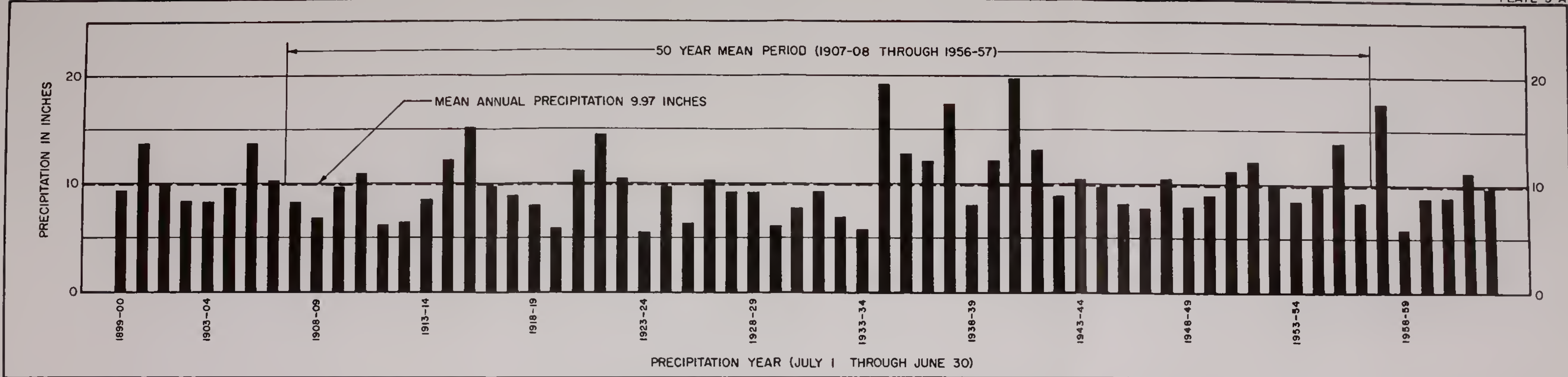


PLATE 3-B



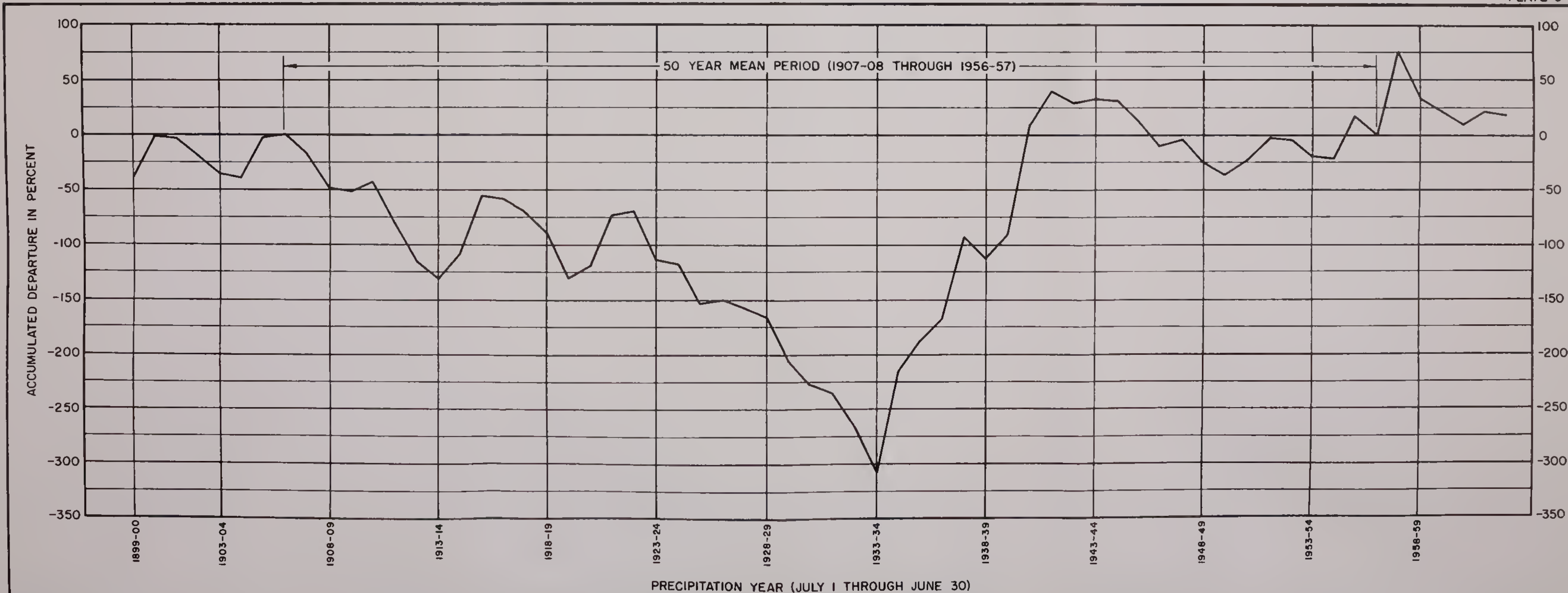
MADERA

PLATE 3-A

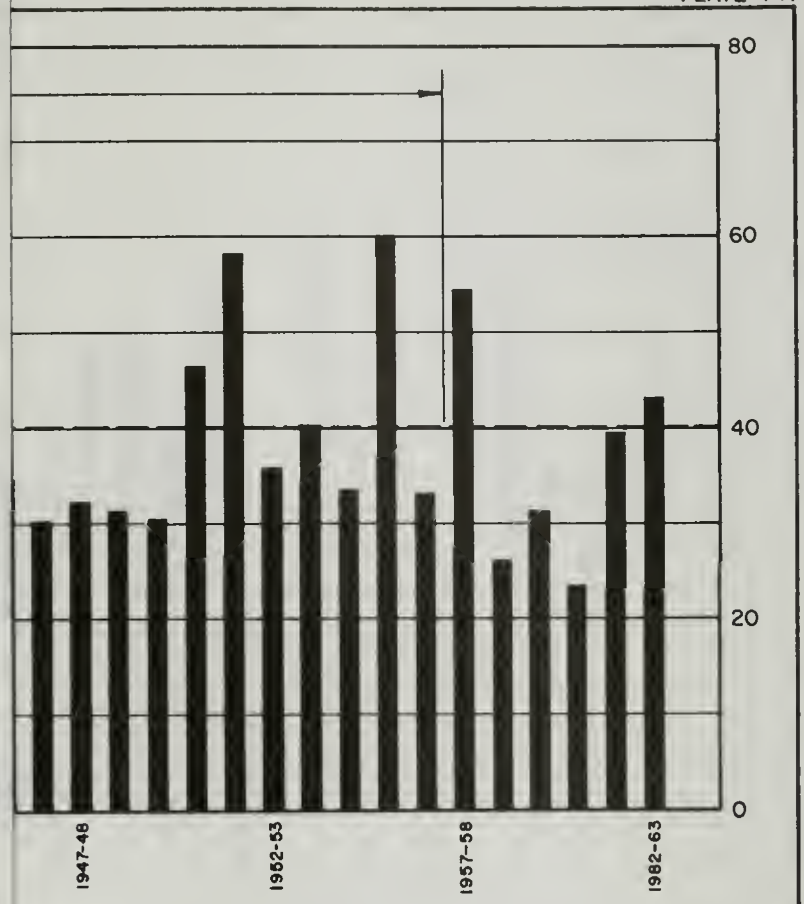


RECORDED ANNUAL PRECIPITATION AT MADERA

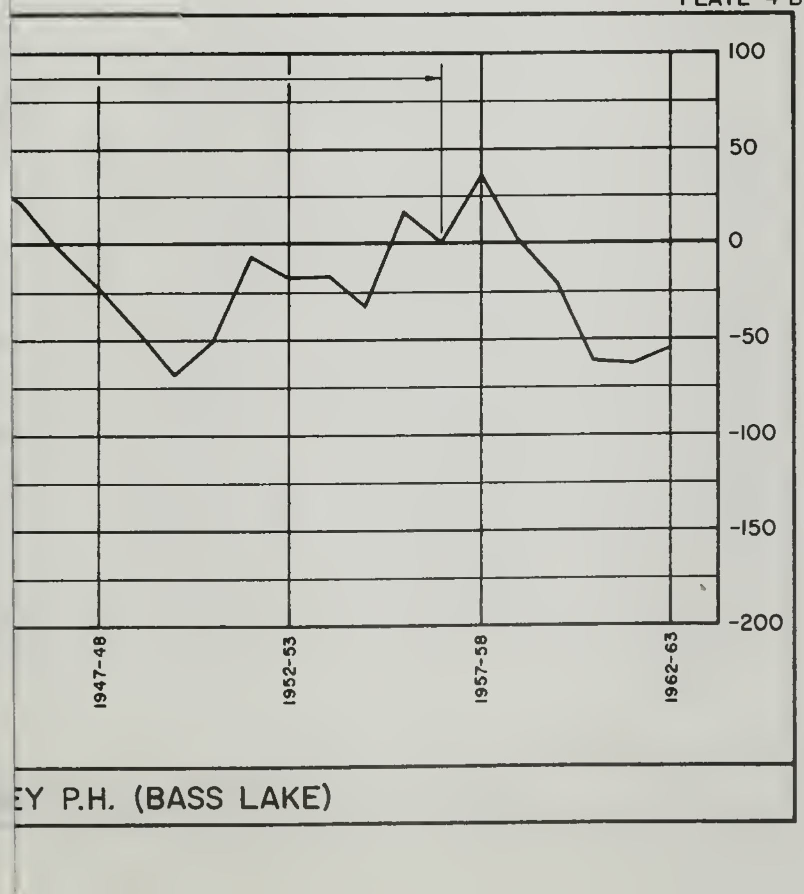
PLATE 3-B



ACCUMULATED DEPARTURE FROM MEAN ANNUAL PRECIPITATION AT MADERA

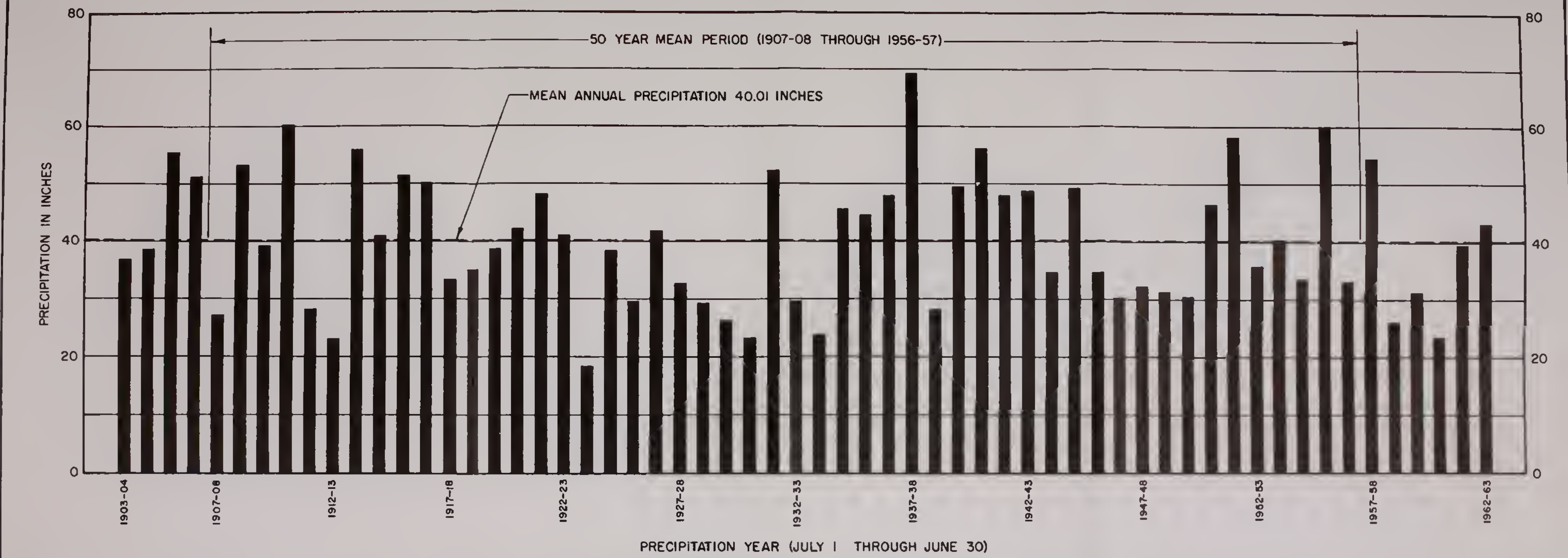


LAKE)



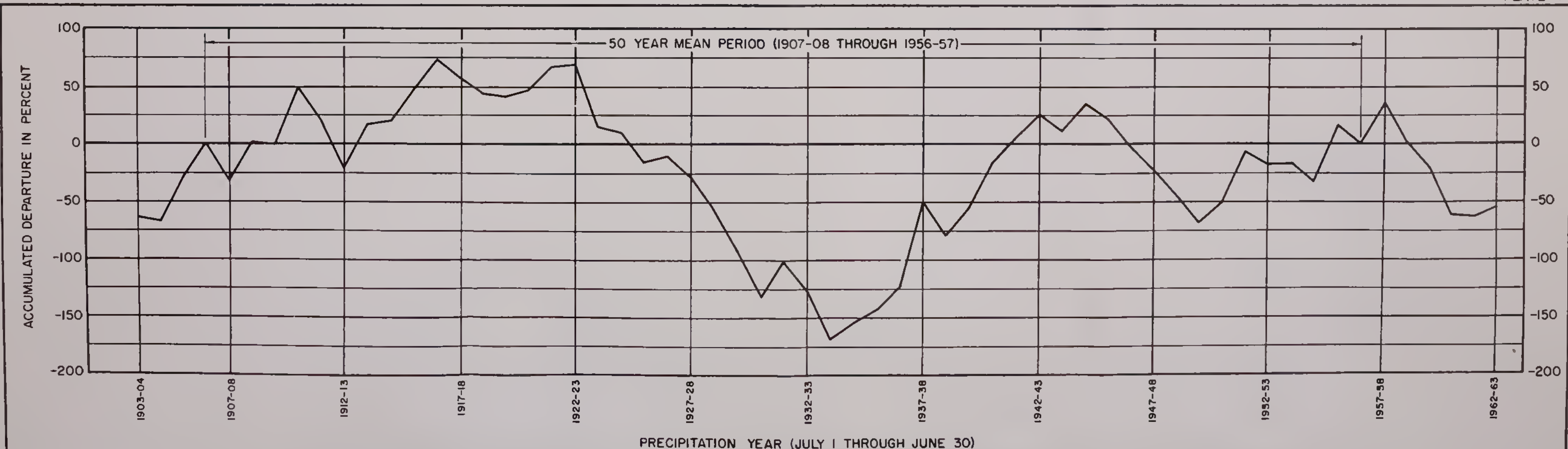
EY P.H. (BASS LAKE)

PLATE 4-A

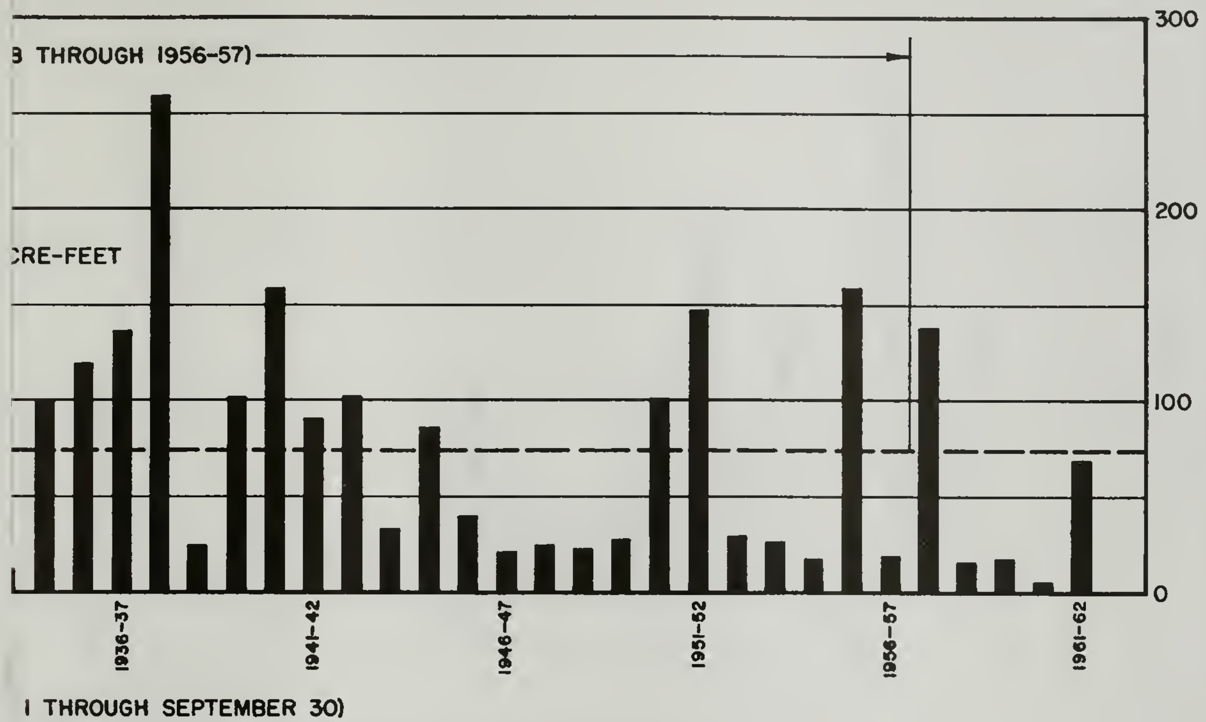


RECORDED ANNUAL PRECIPITATION AT CRANE VALLEY P.H. (BASS LAKE)

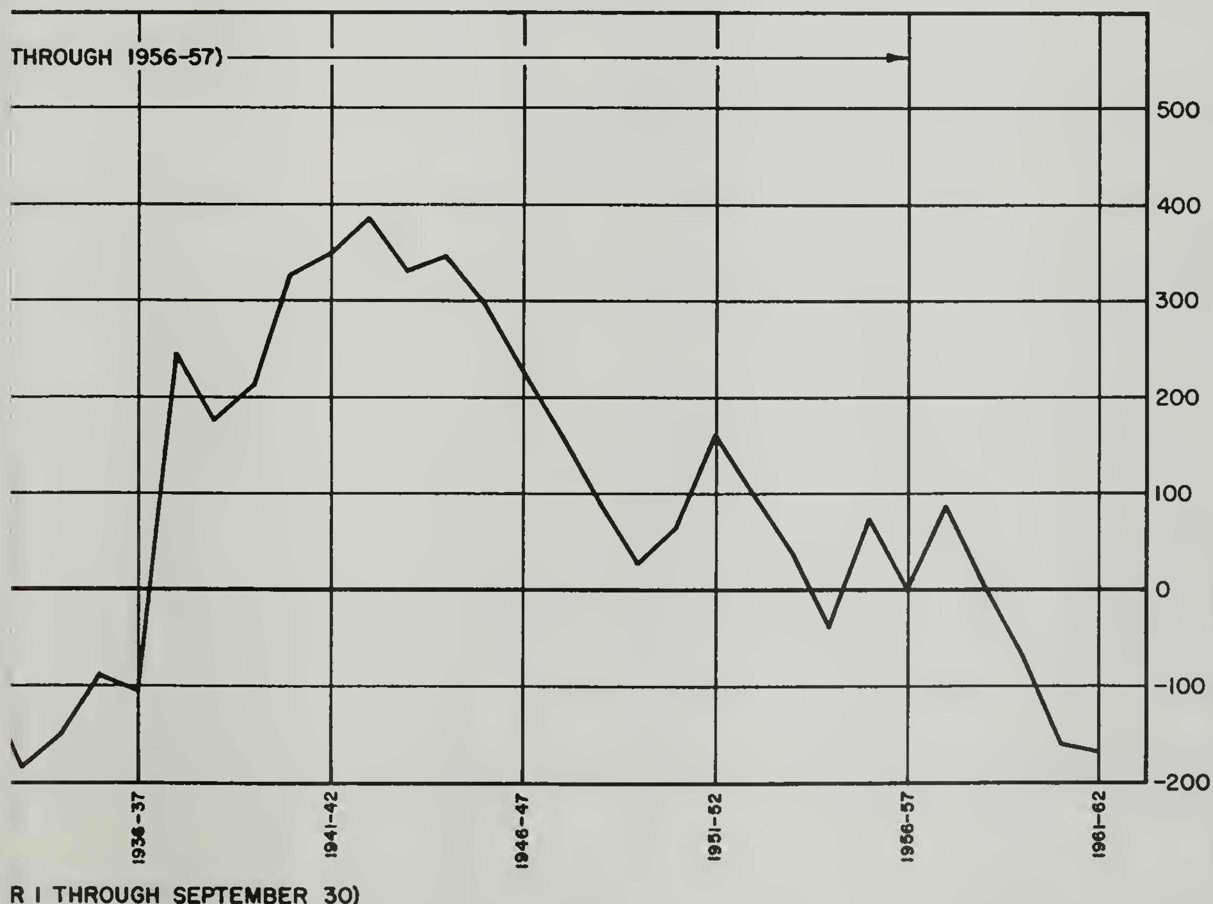
PLATE 4-B



ACCUMULATED DEPARTURE FROM MEAN ANNUAL PRECIPITATION AT CRANE VALLEY P.H. (BASS LAKE)

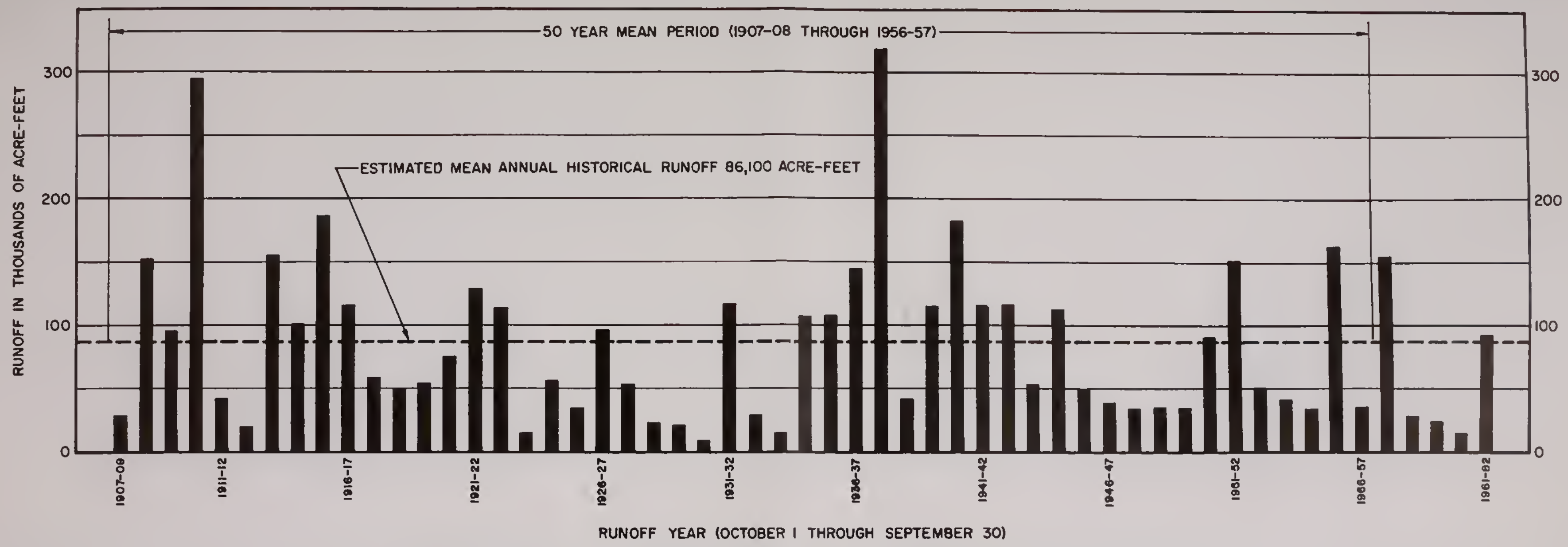


' CHOWCHILLA RIVER AT BUCHANAN DAM SITE



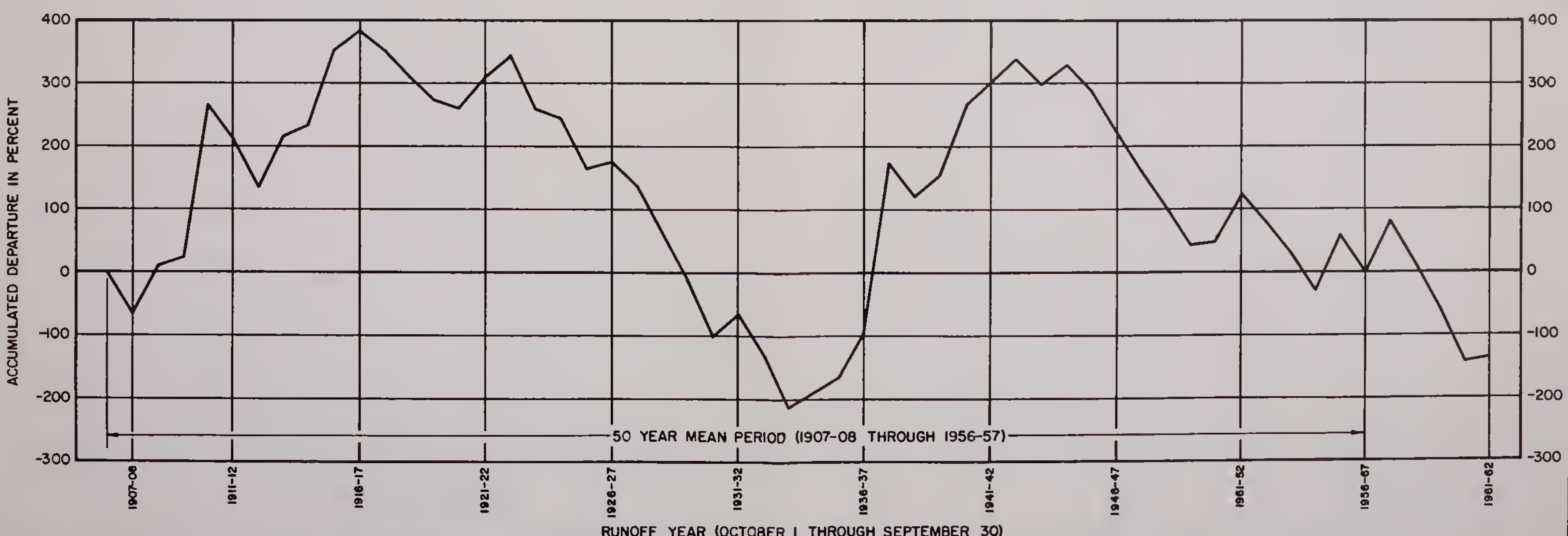
RAL RUNOFF OF CHOWCHILLA RIVER AT BUCHANAN DAM SITE

PLATE 6-A



ESTIMATED ANNUAL HISTORICAL RUNOFF OF FRESNO RIVER NEAR DAULTON

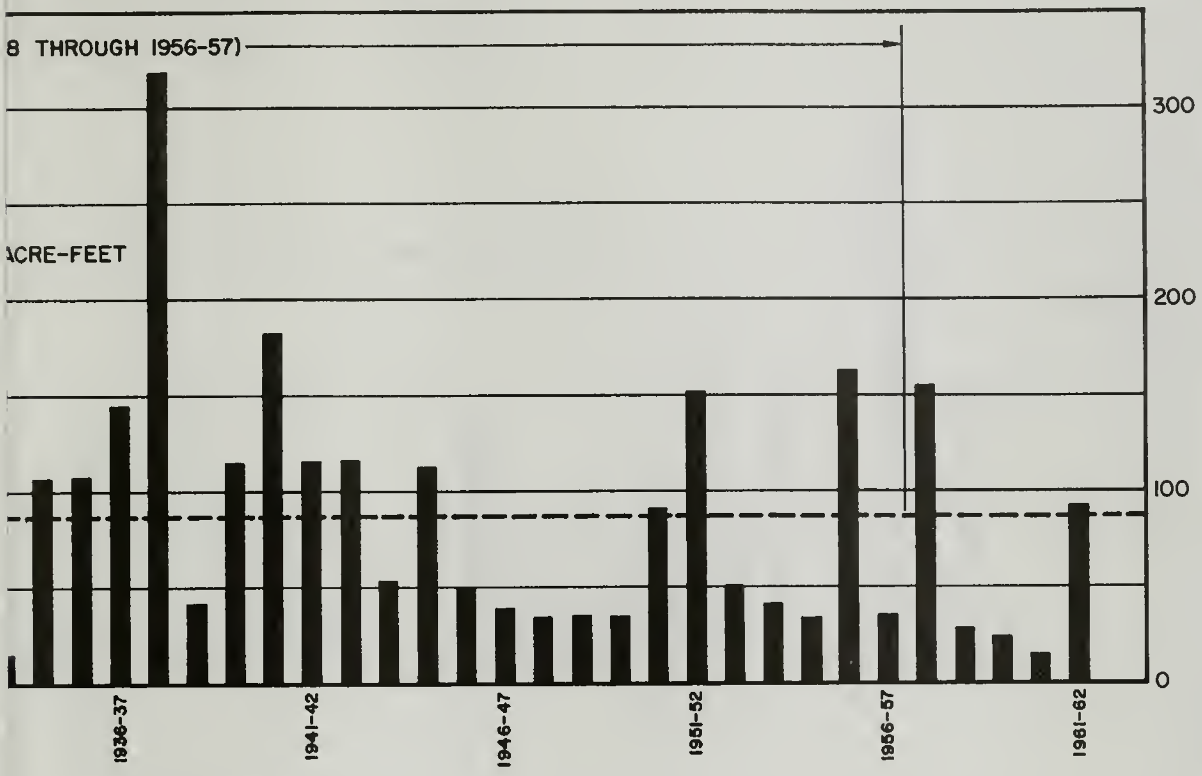
PLATE 6-B



ACCUMULATED DEPARTURE FROM MEAN ANNUAL HISTORICAL RUNOFF OF FRESNO RIVER NEAR DAULTON

DEPARTMENT OF WATER RESOURCES SAN JOAQUIN DISTRICT 1965

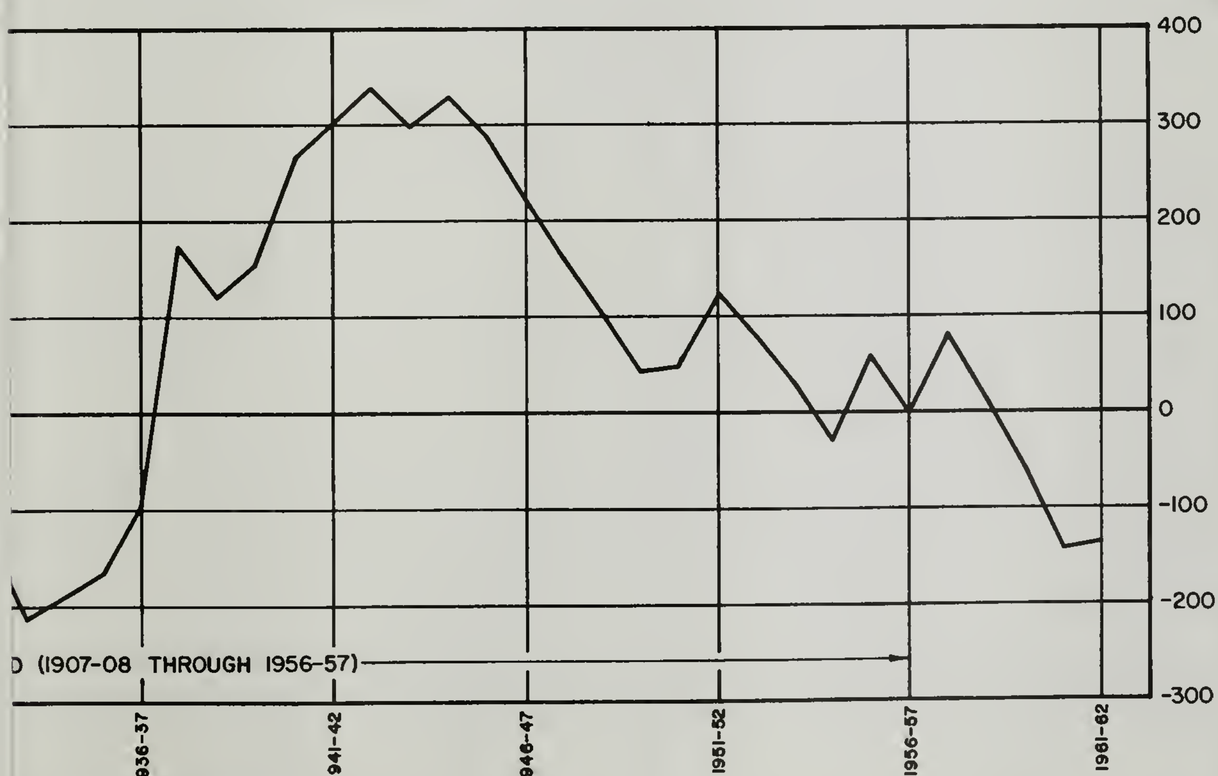
PLATE 6-A



ᴿ I THROUGH SEPTEMBER 30)

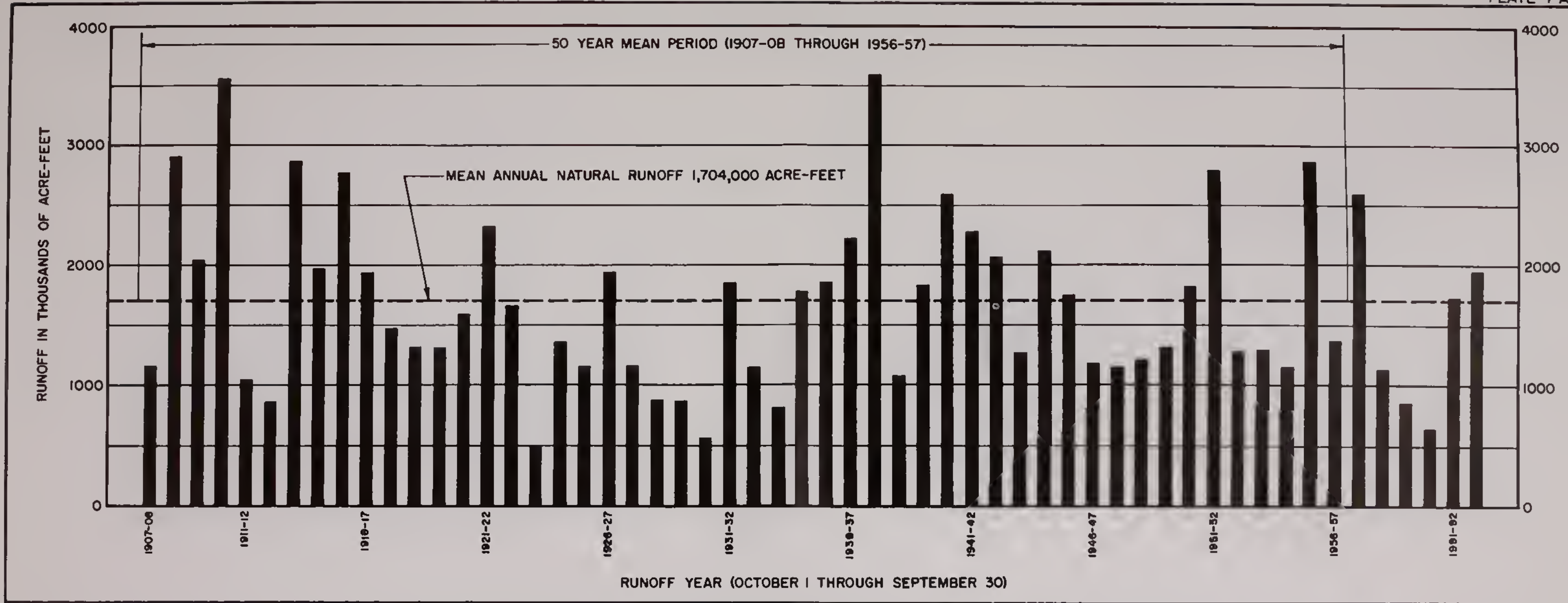
NOFF OF FRESNO RIVER NEAR DAULTON

PLATE 6-B

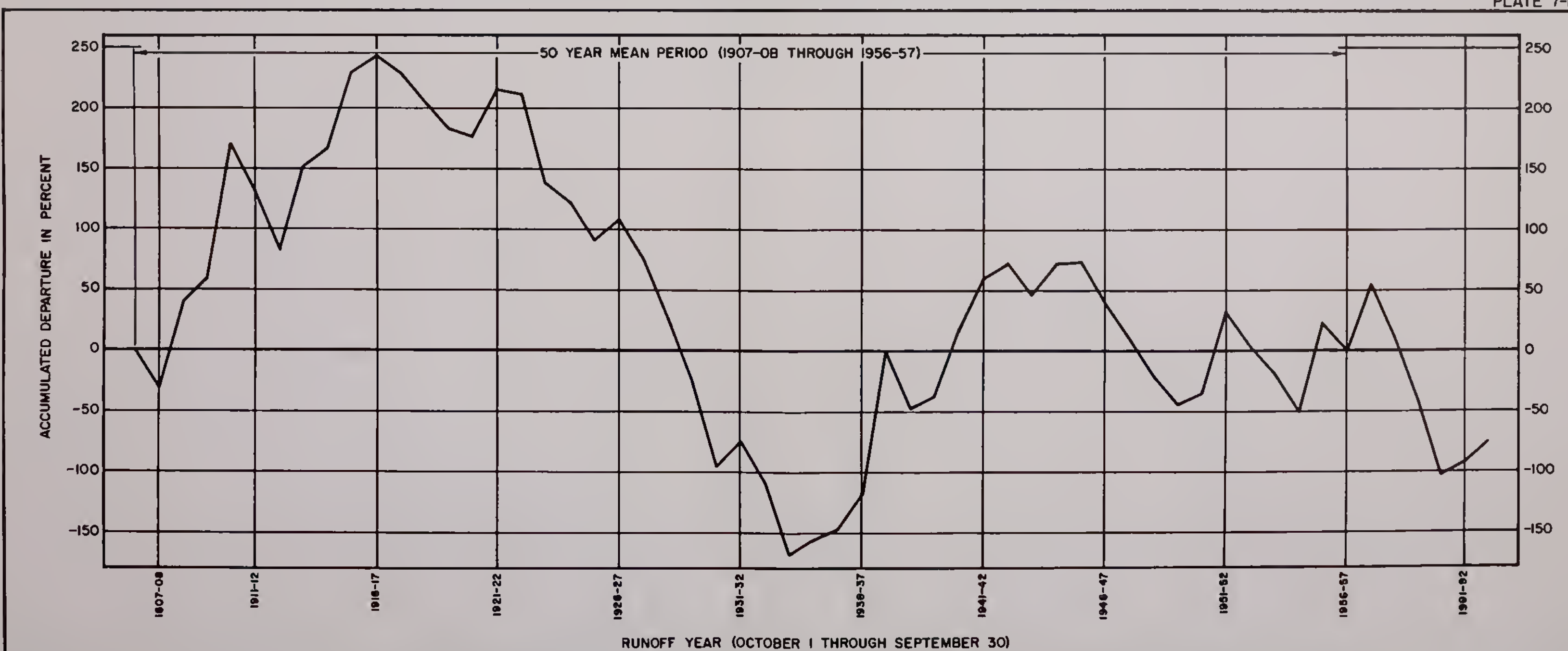


R I THROUGH SEPTEMBER 30)

HISTORICAL RUNOFF OF FRESNO RIVER NEAR DAULTON



ESTIMATED ANNUAL NATURAL RUNOFF OF SAN JOAQUIN RIVER AT FRIANT



ACCUMULATED DEPARTURE FROM MEAN ANNUAL NATURAL RUNOFF OF SAN JOAQUIN RIVER AT FRIANT

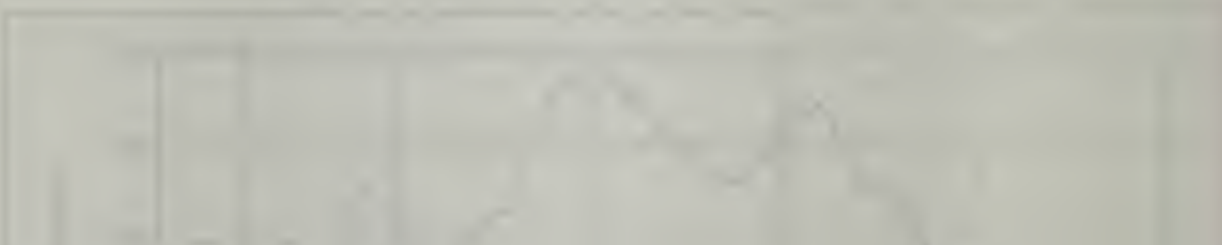
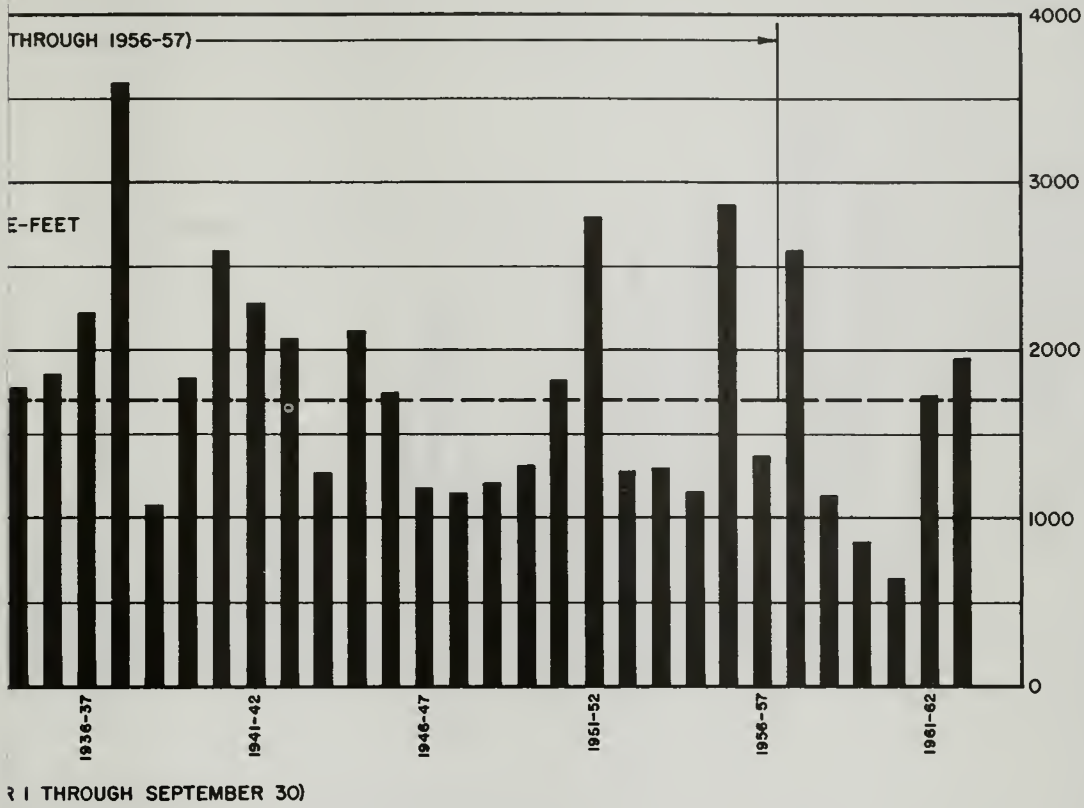
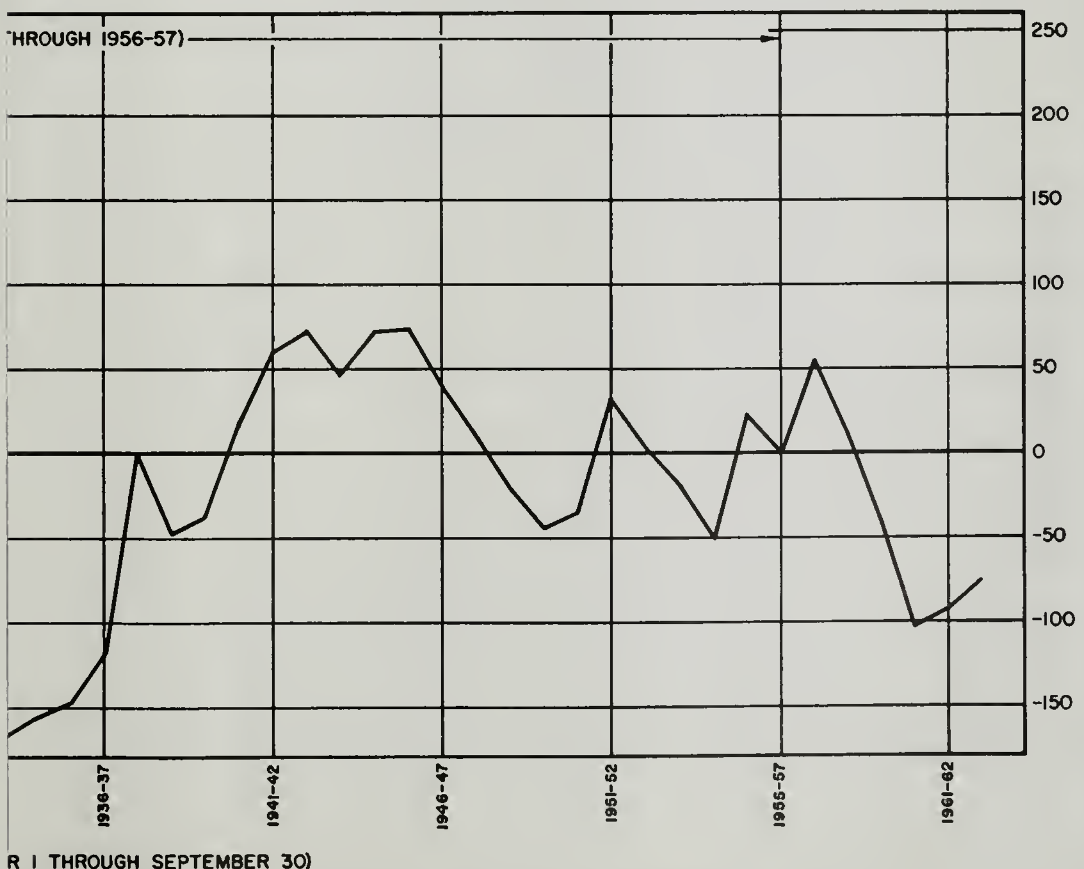


PLATE 7-A

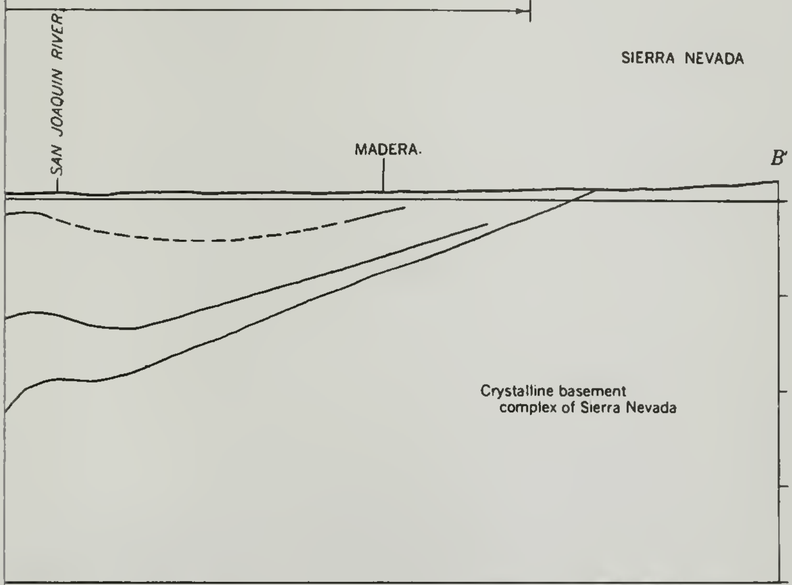


)FF OF SAN JOAQUIN RIVER AT FRIANT

PLATE 7-B



NATURAL RUNOFF OF SAN JOAQUIN RIVER AT FRIANT



SECTION B-B'

BASED ON U.S. GEOLOGICAL SURVEY W.S.P. 1469

N ACROSS THE CENTRAL SAN JOAQUIN VALLEY CALIFORNIA

0 12 Miles

Vertical scale 6.5 times horizontal scale

NOTES :

1 GEOLOGIC SECTIONS ARE FROM DAVIS, G.H., et al., 1959, GROUND-WATER CONDITIONS AND STORAGE CAPACITY IN THE SAN JOAQUIN VALLEY, CALIFORNIA, U. S. GEOLOGICAL SURVEY WATER SUPPLY PAPER 1469.

2. REFER TO PLATE 9 FOR LOCATION OF SECTIONS

3. 1964 WATER LEVELS BY D.W. R.

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STATE OF CALIFORNIA

THE RESOURCES AGENCY

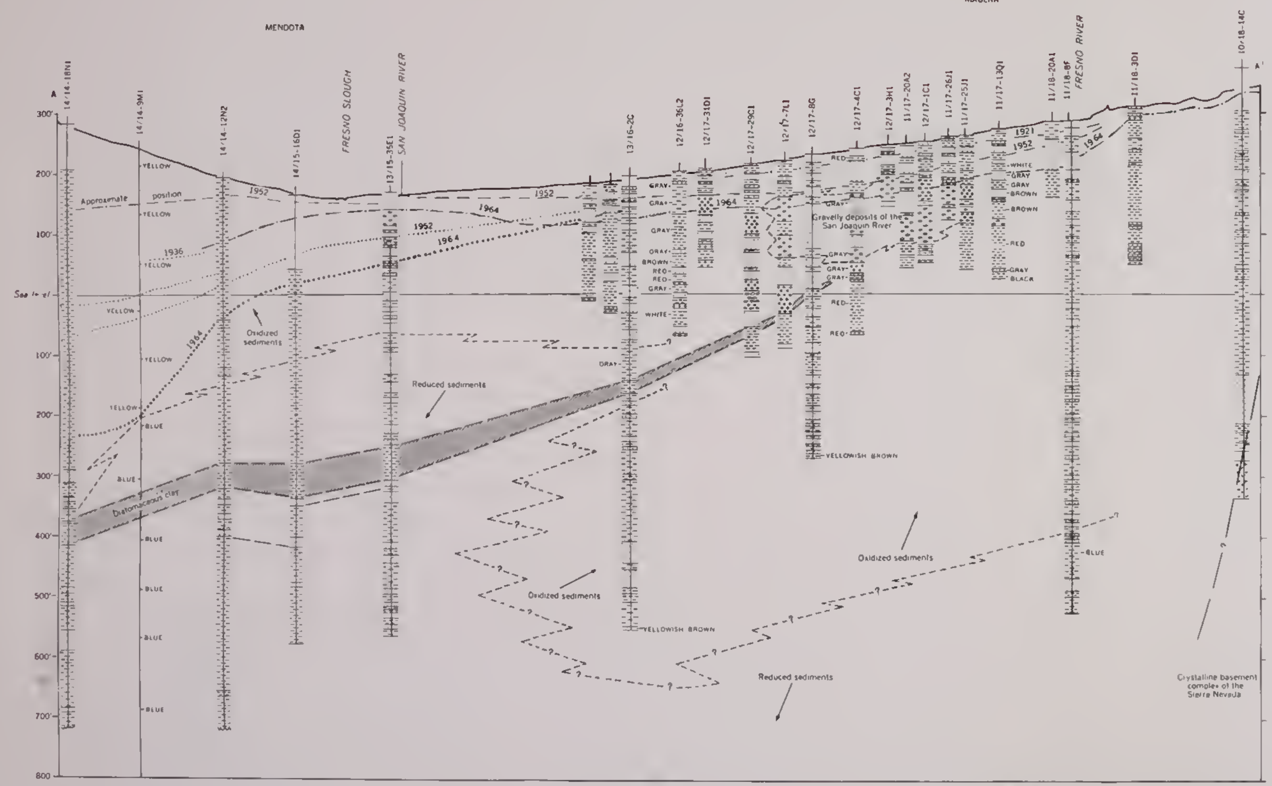
DEPARTMENT OF WATER RESOURCES

SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

GEOLOGIC SECTIONS A-A' AND B-B'

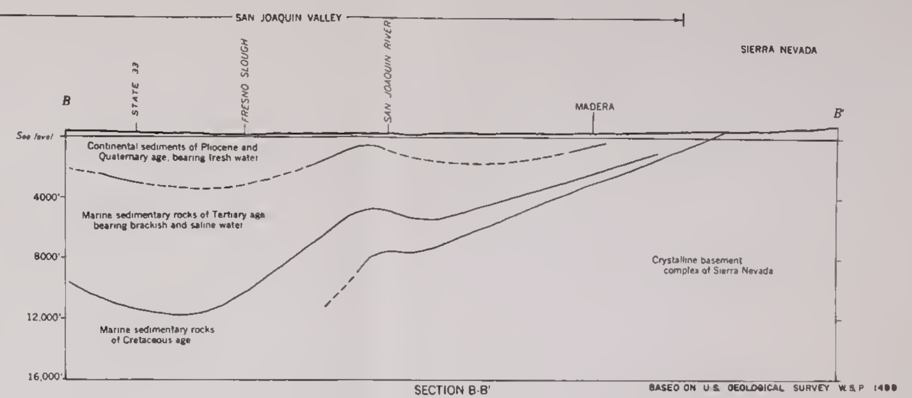
1965



GEOLOGIC SECTION A A'

BASED ON U S GEOLOGICAL SURVEY W S P 1469

Vertical scale 104 times horizontal scale



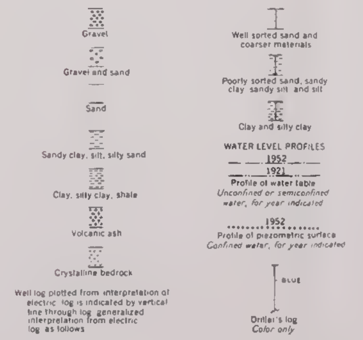
SECTION B-B'

BASED ON U.S. GEOLOGICAL SURVEY W.S.P. 1469

GENERALIZED GEOLOGIC SECTION ACROSS THE CENTRAL SAN JOAQUIN VALLEY CALIFORNIA

Vertical scale 6.5 times horizontal scale

EXPLANATION



NOTES

1. GEOLOGIC SECTIONS ARE FROM DAVIS, G.H., et al, 1959, GROUND-WATER CONDITIONS AND STORAGE CAPACITY IN THE SAN JOAQUIN VALLEY, CALIFORNIA, U S GEOLOGICAL SURVEY WATER SUPPLY PAPER 1469
2. REFER TO PLATE 9 FOR LOCATION OF SECTIONS
3. 1964 WATER LEVELS BY D W R

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

GEOLOGIC SECTIONS A-A' AND B-B'
1965

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Index to Geologic Mapping

1. Davis, G. H., Lofgren, B.E., and Mack, Seymour, 1964.
2. Erwin, Homer D., 1934.
3. U.S. Dept. of Interior, Bureau of Reclamation, 1961.
4. Weir, Walter W., 1956.
5. California Department of Water Resources, 1961-1964. Unpublished.

Symbols

Study Area Boundary

Oakhurst-Ahwanee Area Boundary

Approximate Geologic Contact

A A'

Location of Geologic Sections

Location of wells shown on Section A-A' (USGS Data)

STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES

SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

REGIONAL GEOLOGY

1965

SCALE OF MILES

5 0 5 10

CONTOUR INTERVAL VARIES FROM 50 TO 500 FEET

Legend

Quaternary / Recent

Qf Young Alluvial Fan and Basin Rim Deposits
Alluvial fan deposits of present streams and distributaries; consist of unconsolidated, undeformed sand and silt with lenses of gravel and clay. Basin rim deposits occur in the valley trough portion as fine sand, silt, and clay of the San Joaquin River flood plain. Permeable to moderately permeable.

Qb Basin Deposits
Unconsolidated fine silty and clayey sand, silt, and clay occurring in the valley trough and outer fan areas. Contain alkali and saline water at shallow depths near valley trough area. Poorly to moderately permeable.

Qvb Quaternary Volcanic Rocks, Basalt
Fractured and jointed, dark colored basalt flows. Occur locally in the Sierran crest area, e.g., Devil's Postpile National Monument.

Pleistocene

Qof Old Alluvial Fan Deposits
Old alluvial fan-head, mid-fan and terrace deposits along the eastern edge of the valley. Consist of unconsolidated to loosely consolidated, poorly sorted gravel, sand, and silty clay. Characterized by well developed soils and clay pan; subsoil in part saline. Moderately to poorly permeable.

Tertiary

Tv Tertiary Volcanic Rocks, Undifferentiated
Scattered, local volcanic flows capping portions of the Sierra Nevada. Fractured, jointed, and locally vesicular.

Mio-Pliocene

QTf Friant Formation
Loose to friable fluviatile fan sediments, predominantly sand with interbedded silts and few local gravel lenses. Characterised locally by light colored rhyolitic pumiceous sand and fine gravel content. Moderately to poorly permeable.

Eocene

Ti Ione Formation
Local light colored clay and clayey sandstone along Sierran foothills.

Cretaceous-Jurassic

KJgr Granitic Rock
Intrusive acidic igneous rock forming the Sierra Nevada batholith. Ranges in composition from diorite to granite. Hard and massive where unweathered; soft and friable in some areas where weathering has formed a widespread mantle of "decomposed granite" on the granitic surface.

Pre-Cretaceous

Metamorphic Rocks, Undifferentiated
Pre-Cretaceous metamorphic rocks consisting of steeply dipping, isoclinally folded strata of metasedimentary and metavolcanic rocks.

Index to Geologic Mapping

1. Davis, G. H., Lofgren, B.E., and Mack, Seymour, 1964.
2. Erwin, Homer D., 1934.
3. U.S. Dept. of Interior, Bureau of Reclamation, 1961.
4. Weir, Walter W., 1956.
5. California Department of Water Resources, 1961-1964. Unpublished.

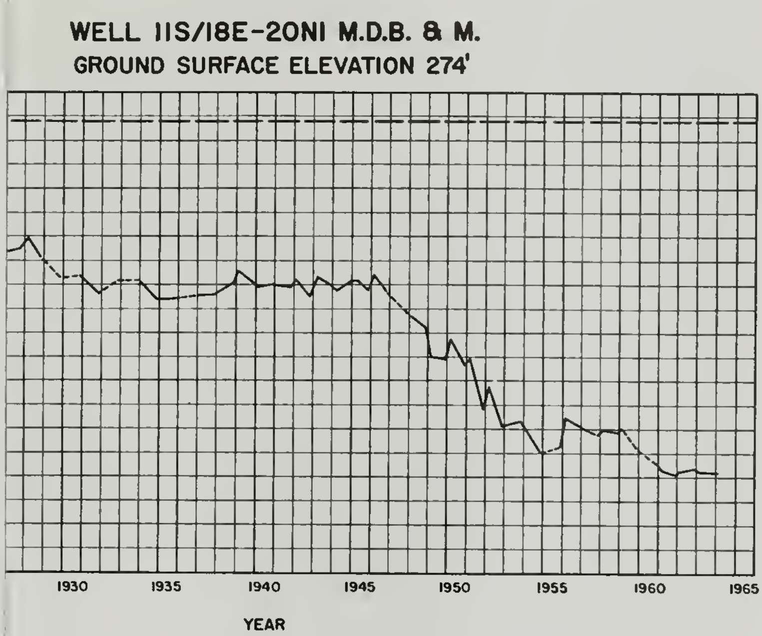
Symbols

- Study Area Boundary
- Oakhurst-Ahwahnee Area Boundary
- Approximate Geologic Contact
- A–A' Location of Geologic Sections
- ● Location of wells shown on Section A-A' (USGS Data)

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

REGIONAL GEOLOGY
1965

SCALE OF MILES



ELEVATION IN FEET-U.S.G.S. DATUM

LEGEND

--------- CONNECTS MEASUREMENTS MADE AT INTERVALS OF A YEAR OR MORE

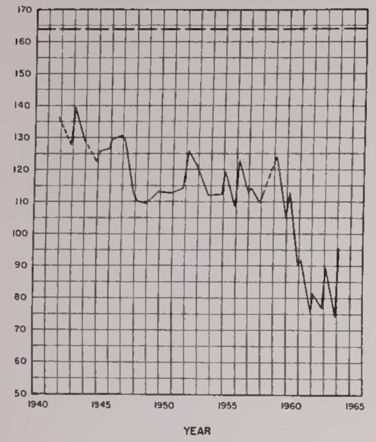
——— GROUND LEVEL

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

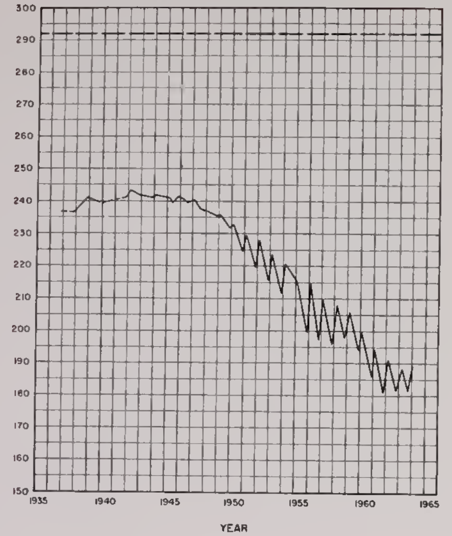
HYDROGRAPHS OF SELECTED WELLS ON THE VALLEY FLOOR
1965

ELEVATION IN FEET-U.S.G.S. DATUM

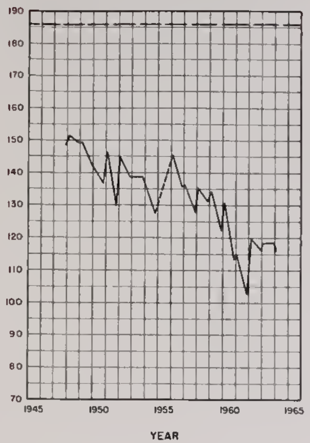
WELL 10S/14E-23A1 M.D.B. & M.
GROUND SURFACE ELEVATION 164'



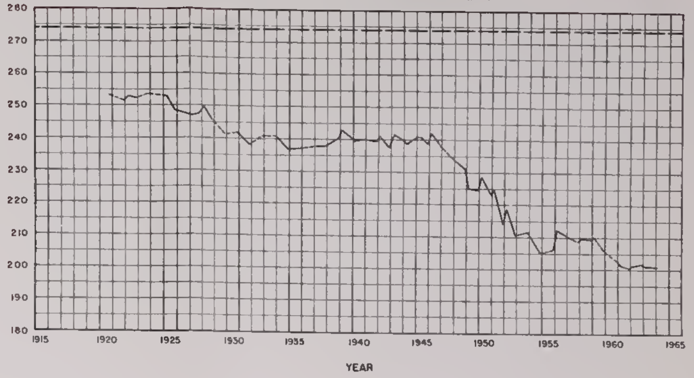
WELL 10S/17E-9A1 M.D.B. & M.
GROUND SURFACE ELEVATION 292'



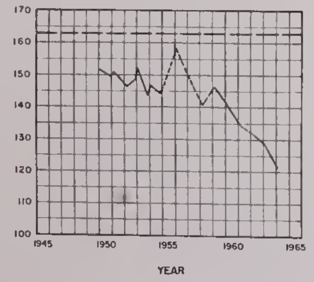
WELL 11S/16E-19R1 M.D.B. & M.
GROUND SURFACE ELEVATION 186'



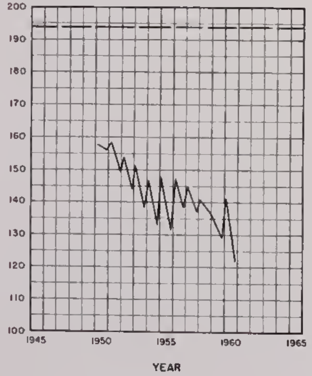
WELL 11S/18E-20N1 M.D.B. & M.
GROUND SURFACE ELEVATION 274'



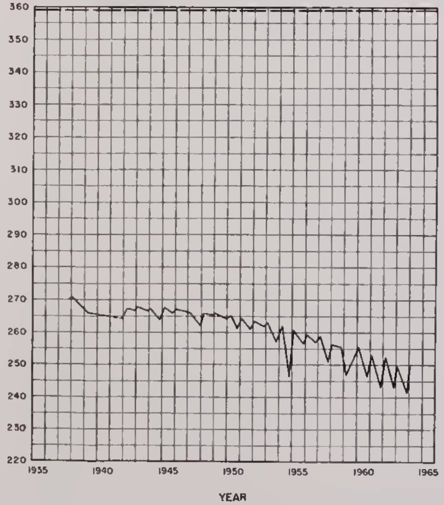
WELL 12S/15E-27C1 M.D.B. & M.
GROUND SURFACE ELEVATION 163'



WELL 12S/16E-27R1 M.D.B. & M.
GROUND SURFACE ELEVATION 194'



WELL 12S/20E-17H1 M.D.B. & M.
GROUND SURFACE ELEVATION 359'



ELEVATION IN FEET-U.S.G.S. DATUM

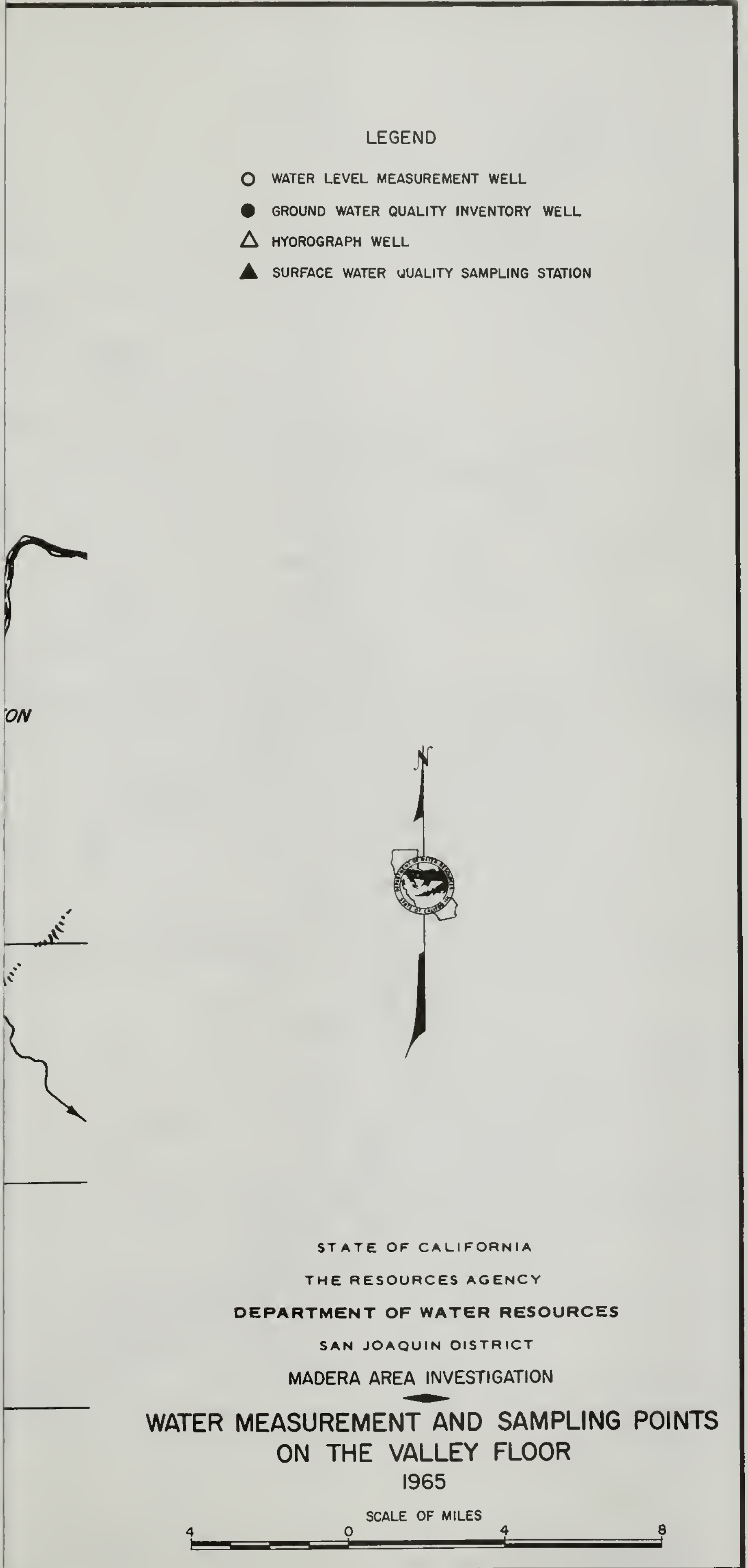
LEGEND

------- CONNECTS MEASUREMENTS MADE AT INTERVALS OF 4 YEAR OR MORE

— — — GROUND LEVEL

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

HYDROGRAPHS OF SELECTED WELLS ON THE VALLEY FLOOR
1965



STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES

SAN JOAQUIN OISTRICT

MADERA AREA INVESTIGATION

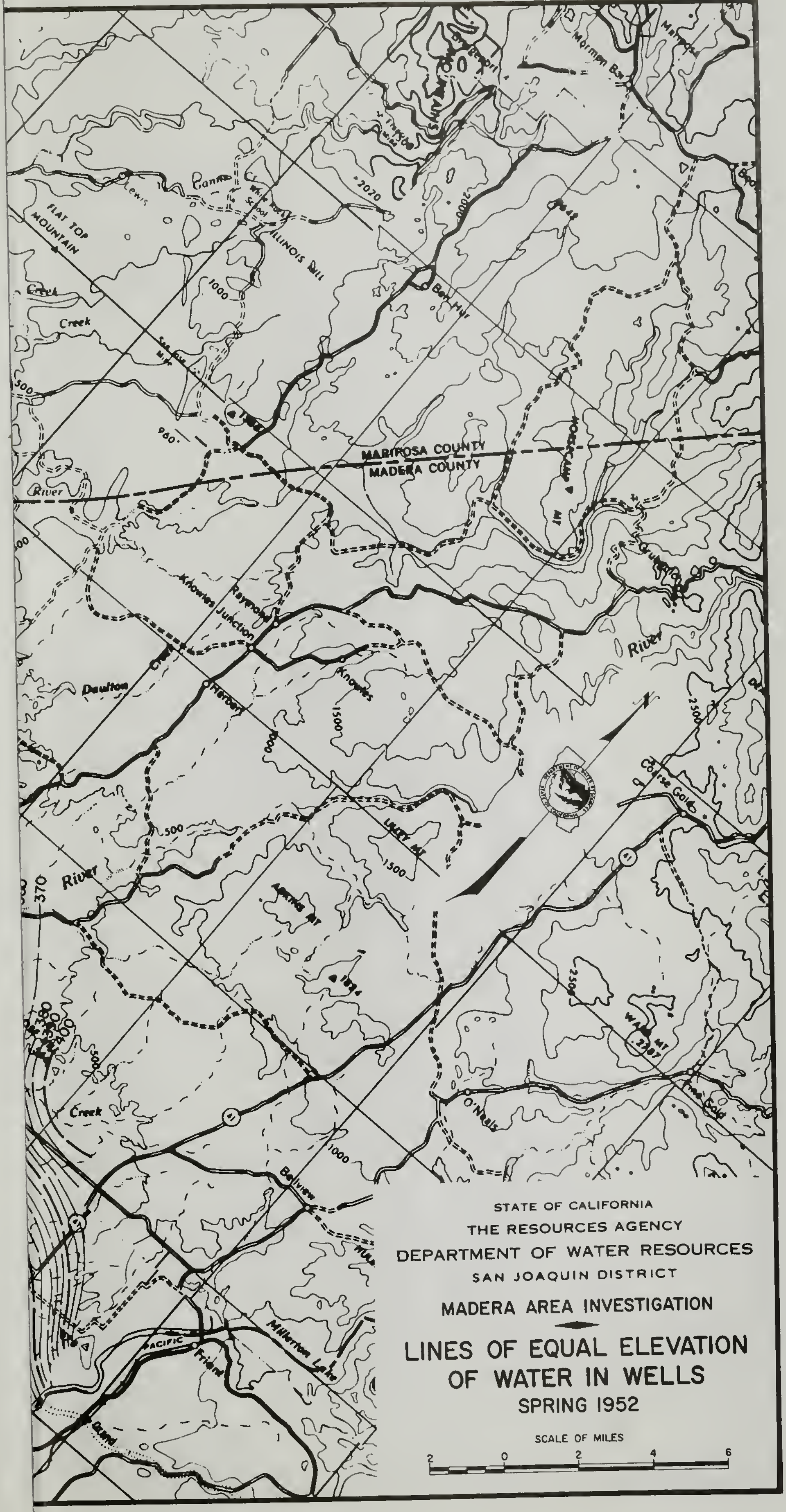
WATER MEASUREMENT AND SAMPLING POINTS ON THE VALLEY FLOOR

1965

PLATE II

LEGEND
WATER LEVEL MEASUREMENT WELL
GROUND WATER QUALITY INVENTORY WELL
HYDROGRAPH WELL
SURFACE WATER QUALITY SAMPLING STATION
MARIPOSA CO.
MERCED CO.
MADERA CO.
FRESNO CO.
CHOWCHILLA RIVER
FRESNO RIVER
SAN JOAQUIN RIVER
MADERA CANAL
FRIANT KERN CANAL
DELTA MENDOTA CANAL
MENDOTA DAM
MILLERTON LAKE
MADERA
FRESNO
R.16E.
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
WATER MEASUREMENT AND SAMPLING POINTS
ON THE VALLEY FLOOR
1965
SCALE OF MILES

PLATE 12



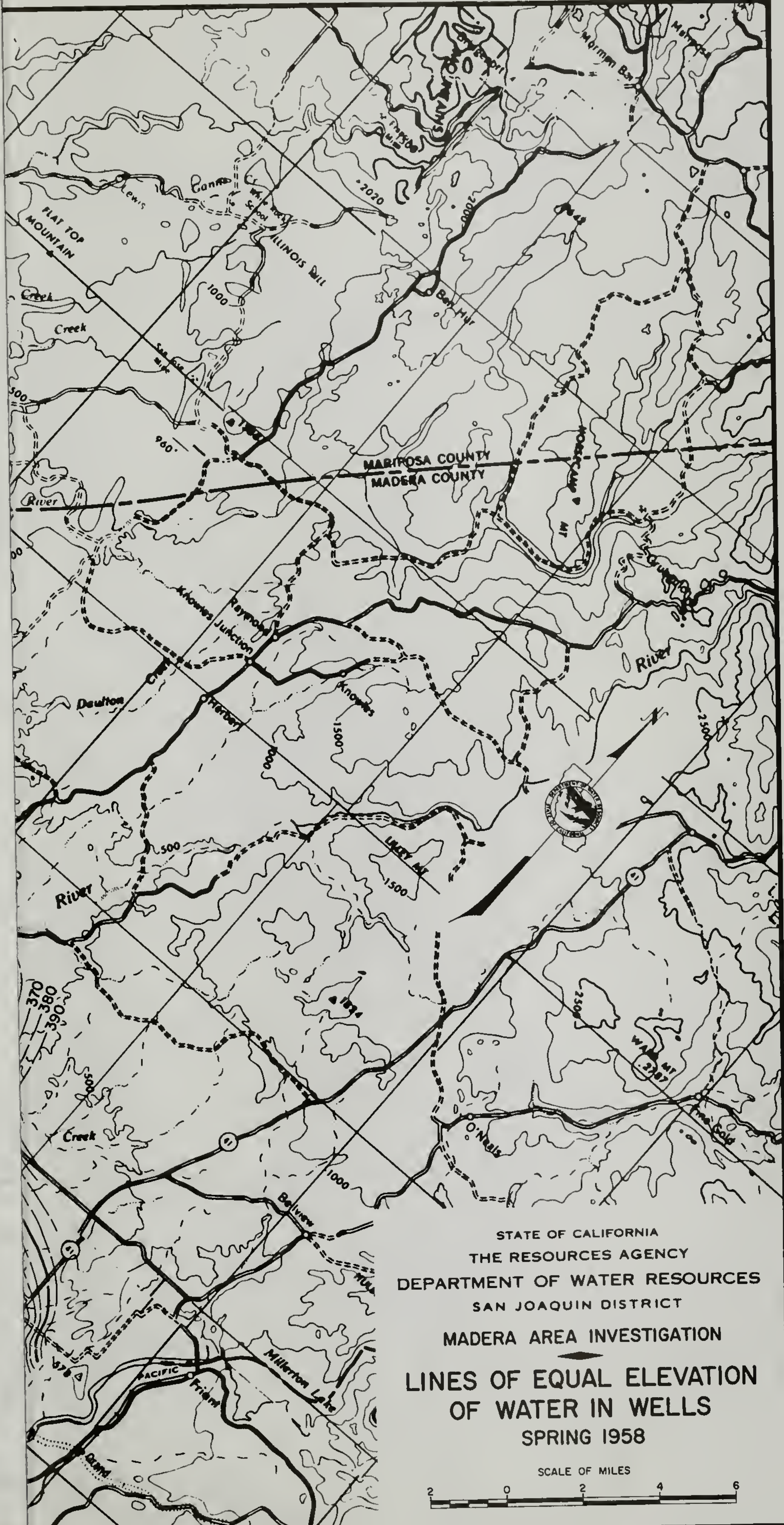
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
LINES OF EQUAL ELEVATION
OF WATER IN WELLS
SPRING 1952
SCALE OF MILES
2 0 2 4 6
MARIPOSA COUNTY
MADERA COUNTY
FLAT TOP MOUNTAIN
Mormon Bar
Lewis
ILLINOIS HILL
Ben Hur
Creek
River
Knowles Junction
Raymond
Knowles
Daulton
Herbert
Coarse Gold
O'Neals
Bellview
Millerton Lake
Friant
PACIFIC
1000
500
1500
2500
960
370
2020

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

LINES OF EQUAL ELEVATION OF WATER IN WELLS
SPRING 1952

SCALE OF MILES
2 0 2 4 6



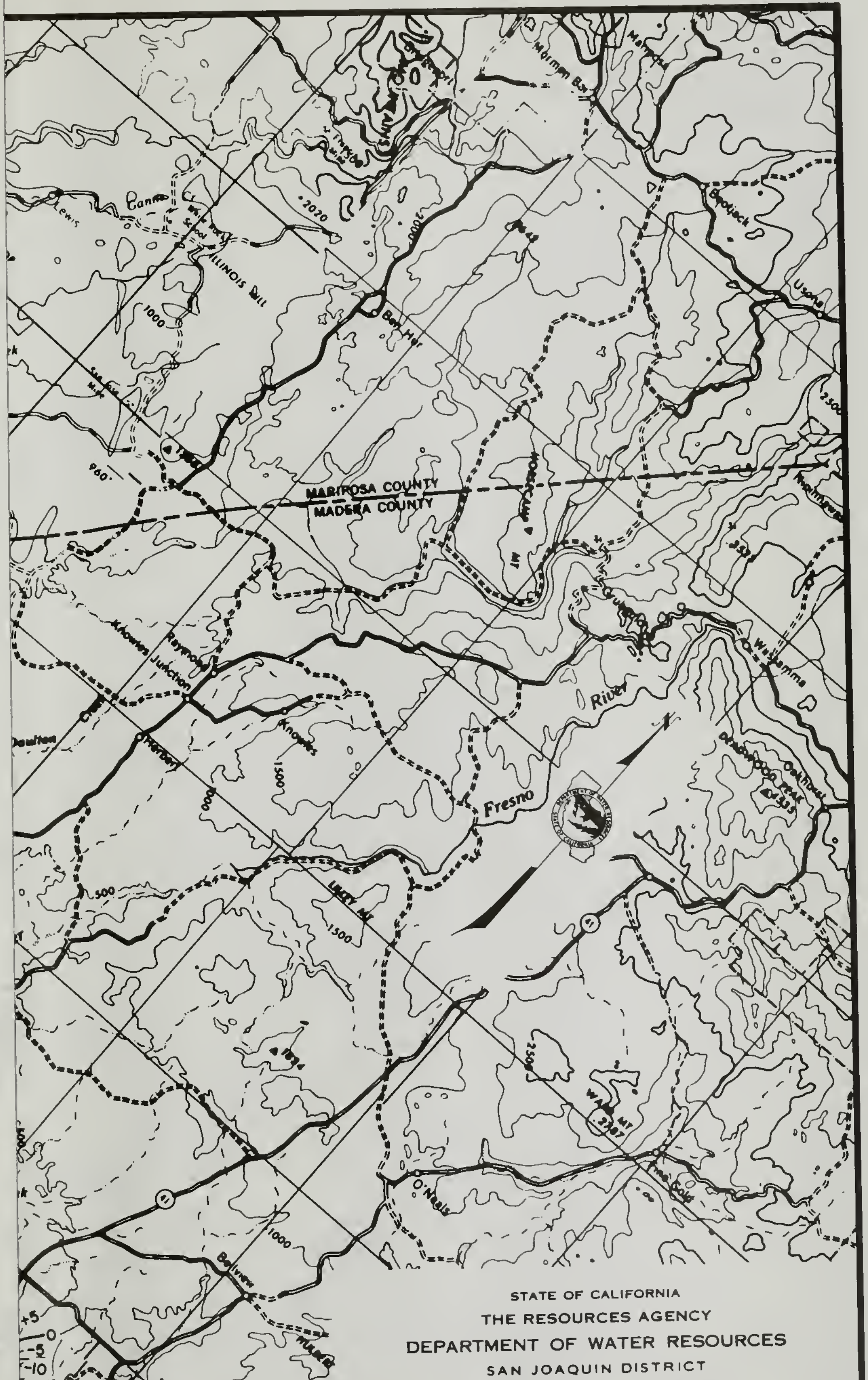
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

LINES OF EQUAL ELEVATION OF WATER IN WELLS
SPRING 1958

SCALE OF MILES
2 0 2 4 6


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
LINES OF EQUAL ELEVATION
OF WATER IN WELLS
SPRING 1958
SCALE OF MILES
2 0 2 4 6
MERCED COUNTY
FRESNO COUNTY
MADERA COUNTY
MARIPOSA COUNTY
Chowchilla
Madera
Kerman
Fresno
Dos Palos
Firebaugh
Mendota
Berenda
Biola
San Joaquin River
Fresno River
Chowchilla River



STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

LINES OF EQUAL CHANGE IN DEPTHS TO WATER ON VALLEY FLOOR
SPRING 1952 TO SPRING 1958

SCALE OF MILES

2 0 2 4 6

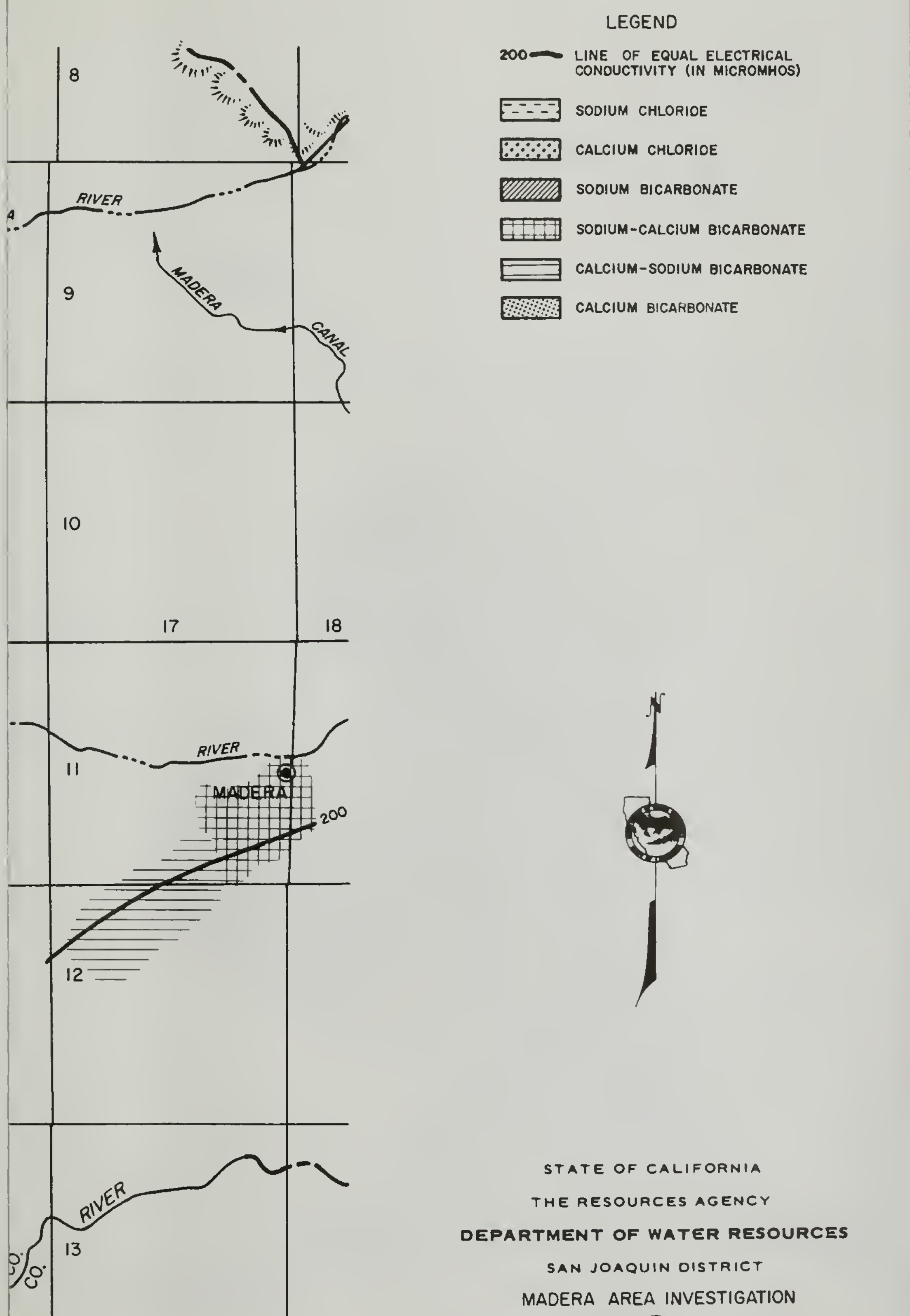
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

LINES OF EQUAL CHANGE IN DEPTHS TO WATER ON VALLEY FLOOR

SPRING 1952 TO SPRING 1958

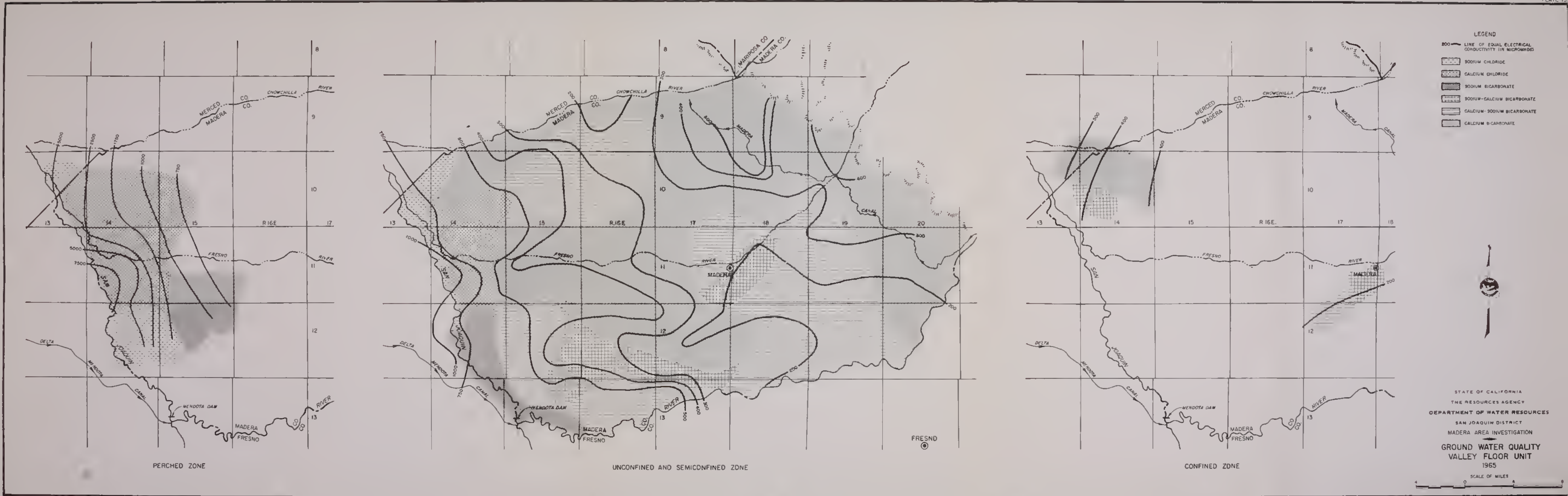
SCALE OF MILES
2 0 2 4 6

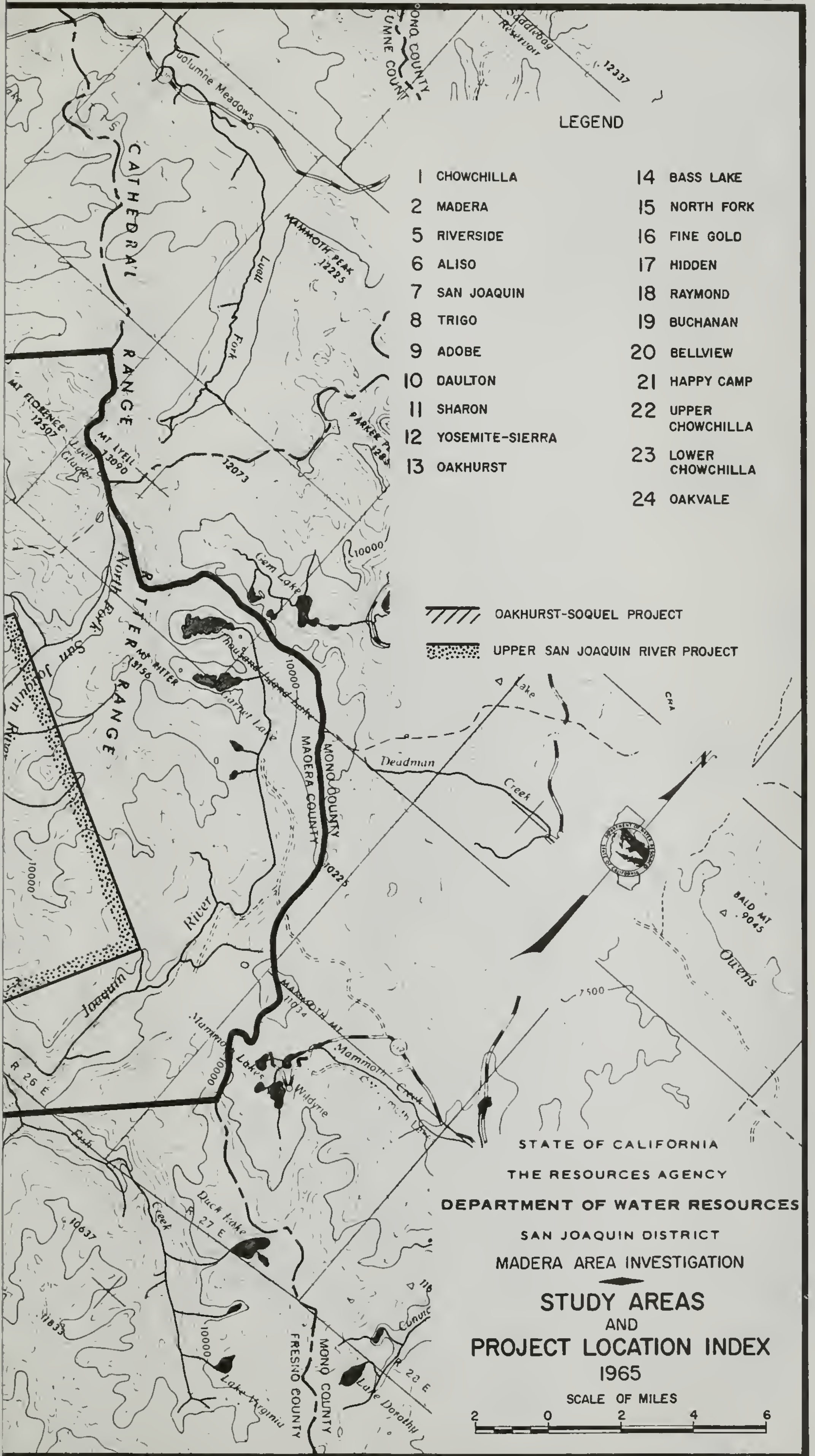


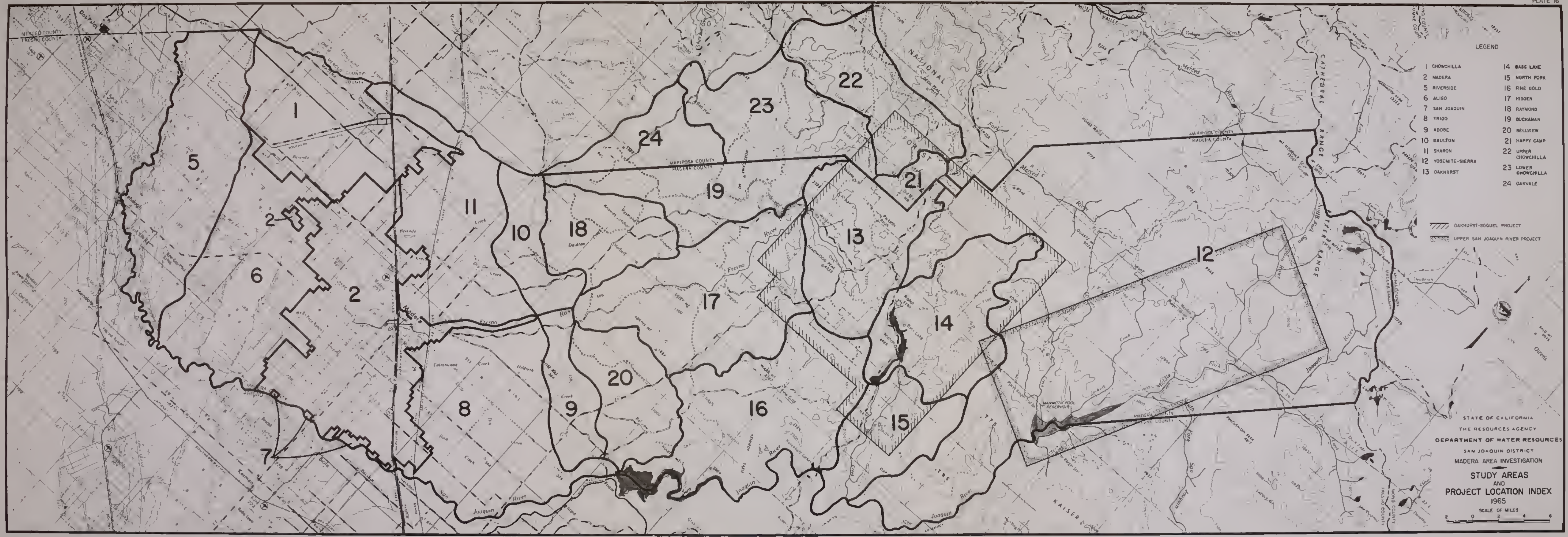
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

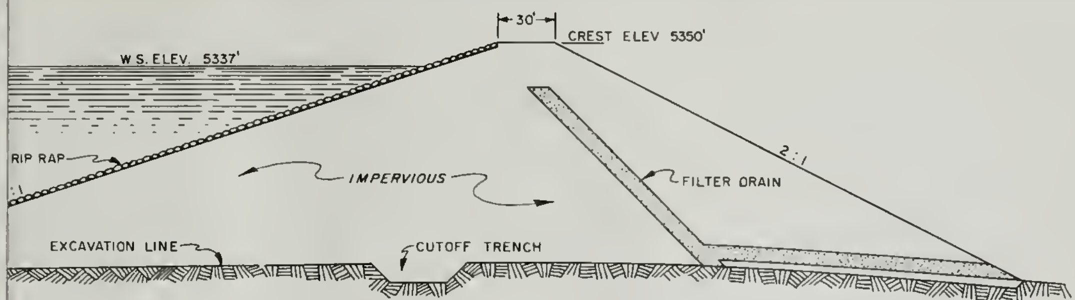
GROUND WATER QUALITY VALLEY FLOOR UNIT 1965

SCALE OF MILES
4 0 4 8


LEGEND
200 LINE OF EQUAL ELECTRICAL CONDUCTIVITY (IN MICROMHOS)
SODIUM CHLORIDE
CALCIUM CHLORIDE
SODIUM BICARBONATE
SODIUM-CALCIUM BICARBONATE
CALCIUM-SODIUM BICARBONATE
CALCIUM BICARBONATE
MERCED
MADERA
CO.
CHOWCHILLA
RIVER
MARIPOSA CO
MADERA CO.
FRESNO
SAN
JOAQUIN
DELTA
MENDOTA
CANAL
MENDOTA DAM
MADERA
R.16E
PERCHED ZONE
UNCONFINED AND SEMICONFINED ZONE
CONFINED ZONE
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
GROUND WATER QUALITY
VALLEY FLOOR UNIT
1965
SCALE OF MILES

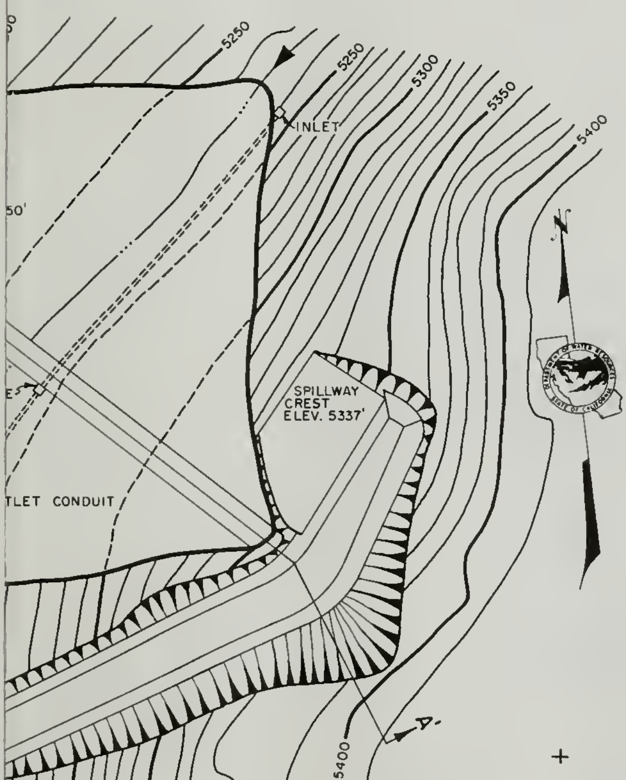

LEGEND
1 CHOWCHILLA
2 MADERA
5 RIVERSIDE
6 ALISO
7 SAN JOAQUIN
8 TRIGO
9 ADOBE
10 DAULTON
11 SHARON
12 YOSEMITE-SIERRA
13 OAKHURST
14 BASS LAKE
15 NORTH FORK
16 FINE GOLD
17 HIDDEN
18 RAYMOND
19 BUCHANAN
20 BELLVIEW
21 HAPPY CAMP
22 UPPER CHOWCHILLA
23 LOWER CHOWCHILLA
24 OAKVALE
OAKHURST-SOQUEL PROJECT
UPPER SAN JOAQUIN RIVER PROJECT
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
STUDY AREAS
AND
PROJECT LOCATION INDEX
1965
SCALE OF MILES
2 0 2 4 6
MONO COUNTY
MADERA COUNTY
FRESNO COUNTY
CATHEDRAL RANGE
RITTER RANGE
MT LYELL 13090
MT RITTER 13156
MAMMOTH PEAK 12225
Tuolumne Meadows
Lyell Fork
Gem Lake
Garnet Lake
Thousand Island Lake
North Fork San Joaquin River
Deadman Creek
Owens
BALD MT 9045
Mammoth Lakes
Mammoth Creek
Duck Lake
Fish Creek
Lake Virginia
Lake Dorothy
R 26 E
R 27 E


LEGEND
1 CHOWCHILLA
2 MADERA
5 RIVERSIDE
6 ALISO
7 SAN JOAQUIN
8 TRIGO
9 ADOBE
10 DAULTON
11 SHARON
12 YOSEMITE-SIERRA
13 OAKHURST
14 BASS LAKE
15 NORTH FORK
16 FINE GOLD
17 HIDDEN
18 RAYMOND
19 BUCHANAN
20 BELLVIEW
21 HAPPY CAMP
22 UPPER CHOWCHILLA
23 LOWER CHOWCHILLA
24 OAKVALE
OAKHURST-SOQUEL PROJECT
UPPER SAN JOAQUIN RIVER PROJECT
MERCED COUNTY
FRESNO COUNTY
MARIPOSA COUNTY
MADERA COUNTY
NATIONAL
FOREST
CATHEDRAL RANGE
RITTER RANGE
MAMMOTH POOL RESERVOIR
Fresno
River
San Joaquin River
Madera
Daulton
KAISER
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
STUDY AREAS
AND
PROJECT LOCATION INDEX
1965
SCALE OF MILES
2 0 2 4 6



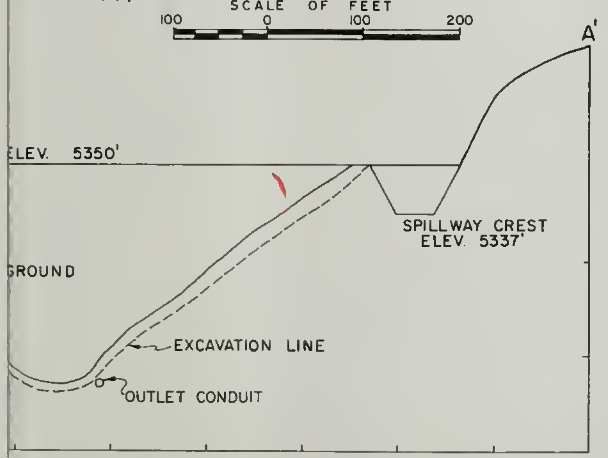
SECTION OF DAM

SCALE OF FEET
50 0 50 100



GENERAL PLAN

SCALE OF FEET
100 0 100 200



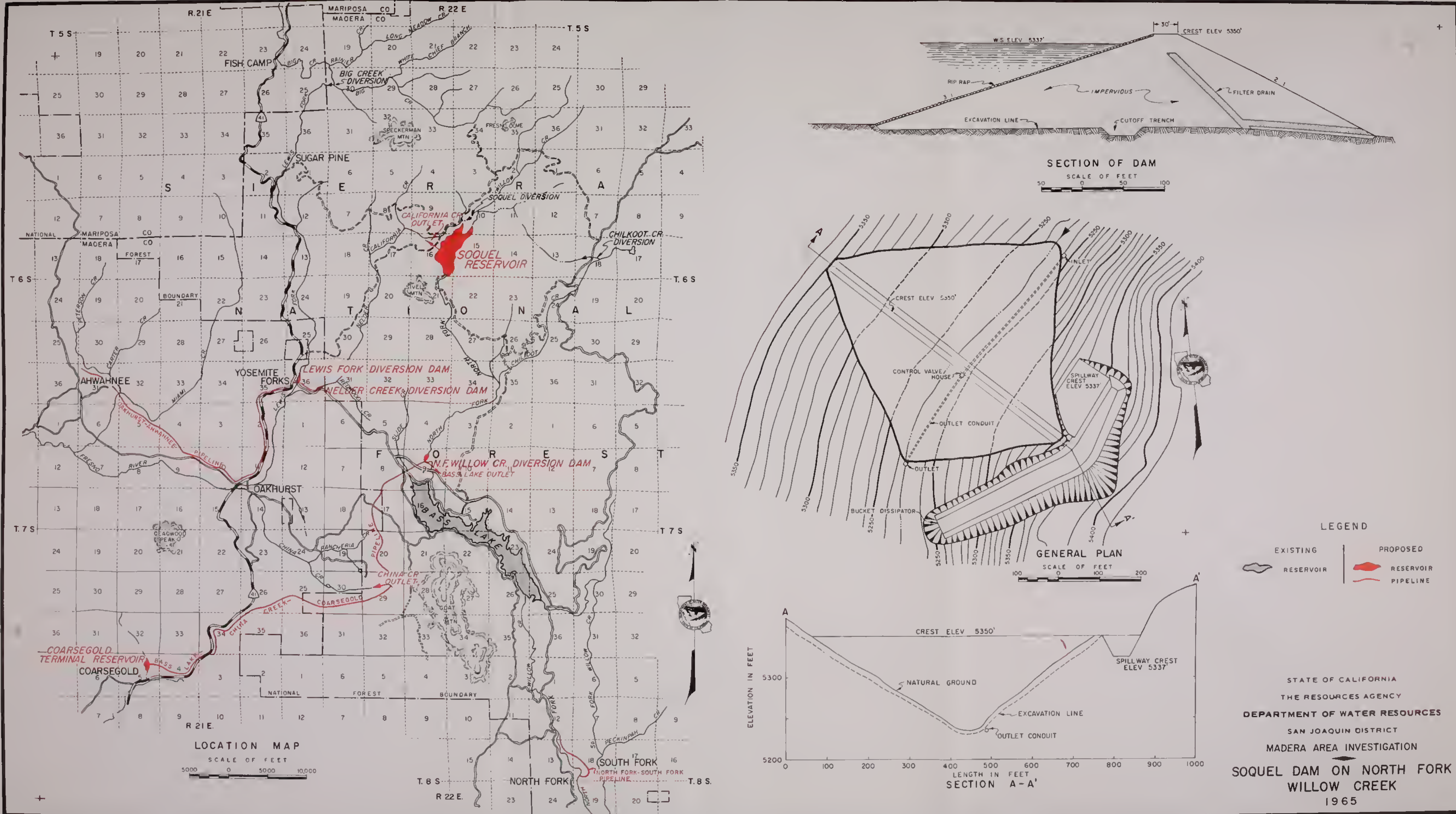
SECTION A-A'

LEGEND

EXISTING		PROPOSED
RESERVOIR		RESERVOIR
		PIPELINE

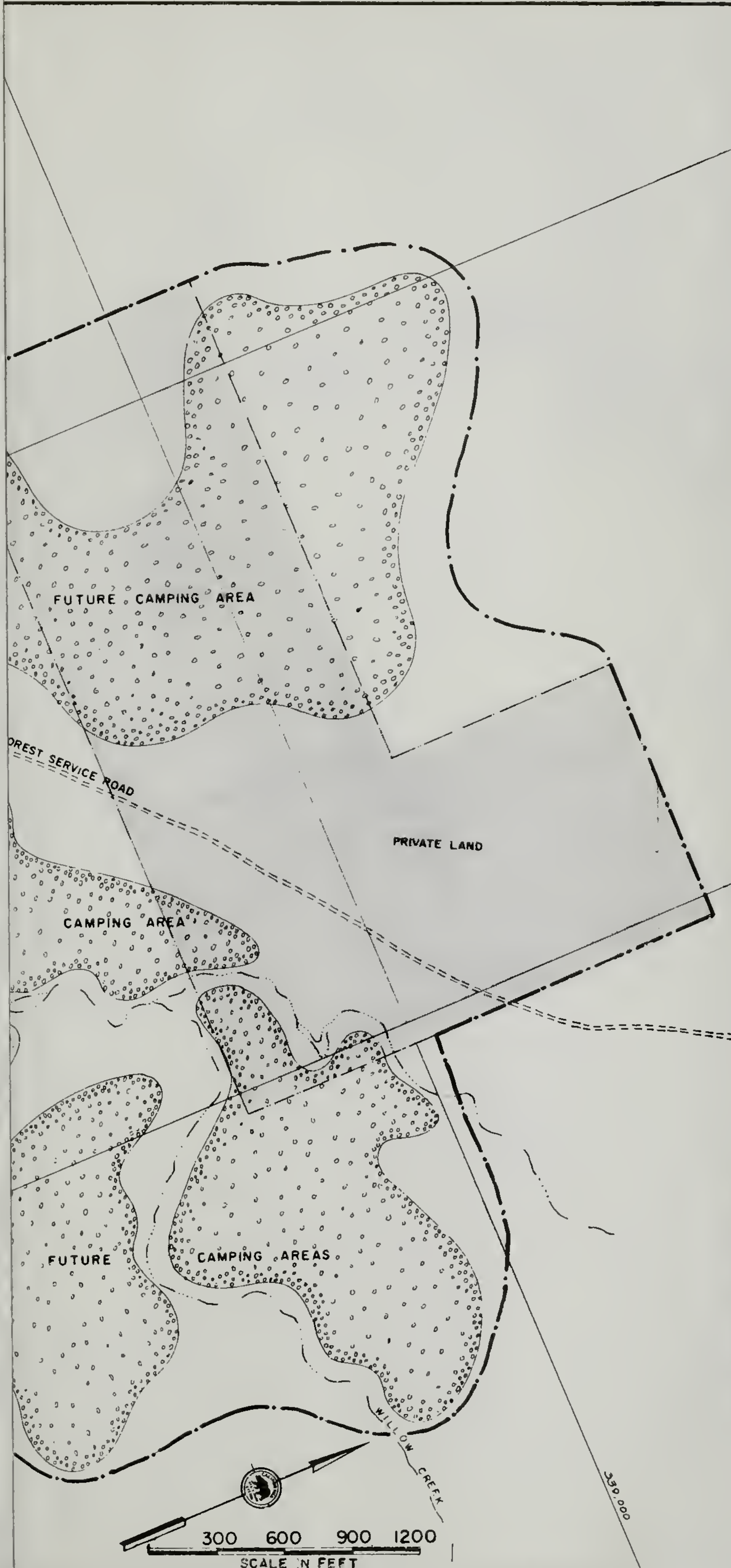
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

SOQUEL DAM ON NORTH FORK WILLOW CREEK
1965



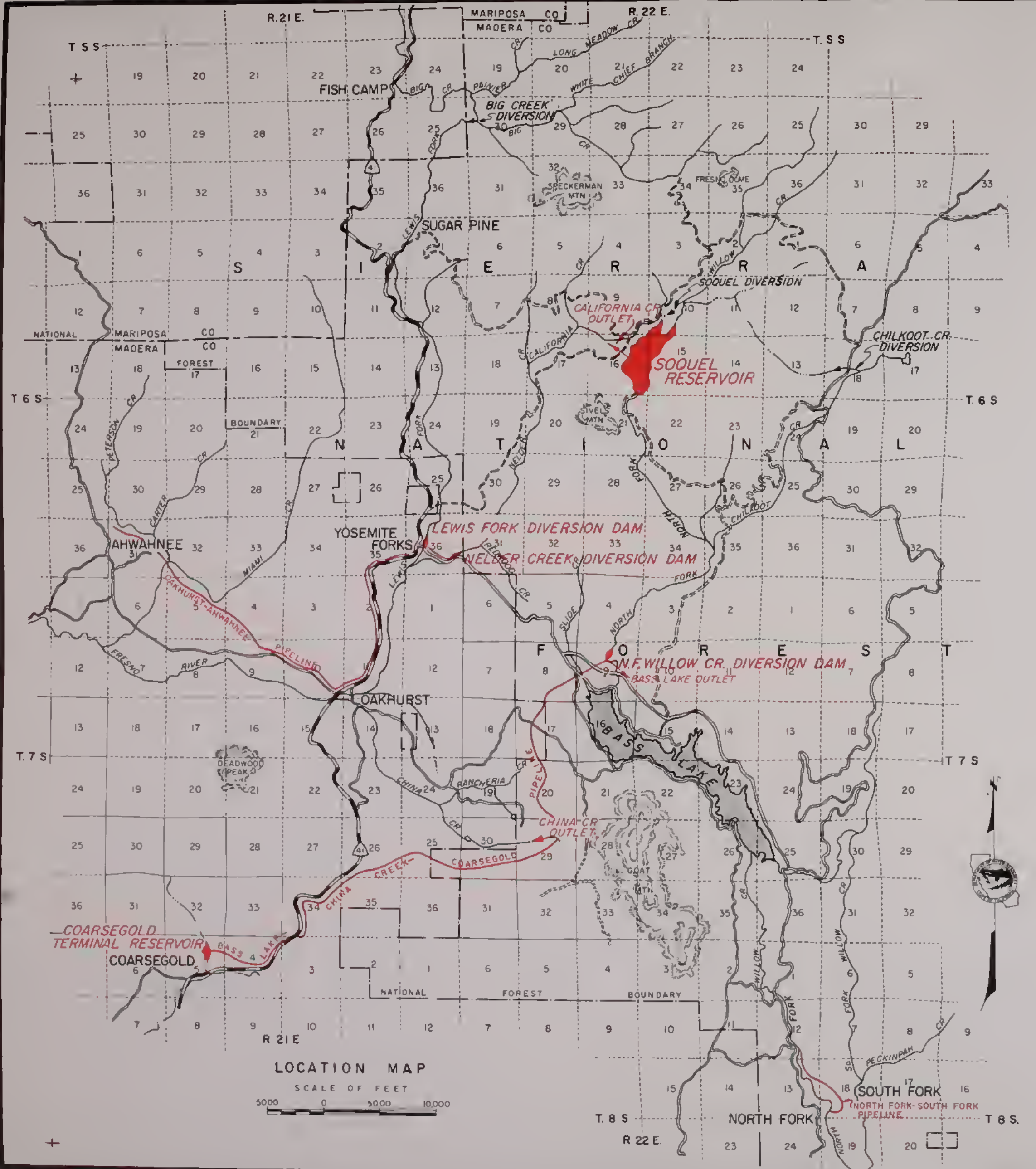
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

SOQUEL DAM ON NORTH FORK WILLOW CREEK
1965

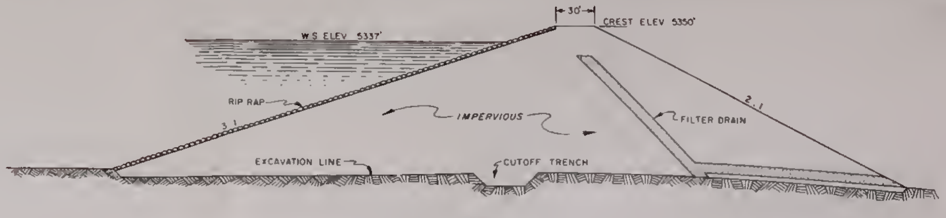


MADERA AREA INVESTIGATION
SOQUEL RESERVOIR
LAND USE PLAN

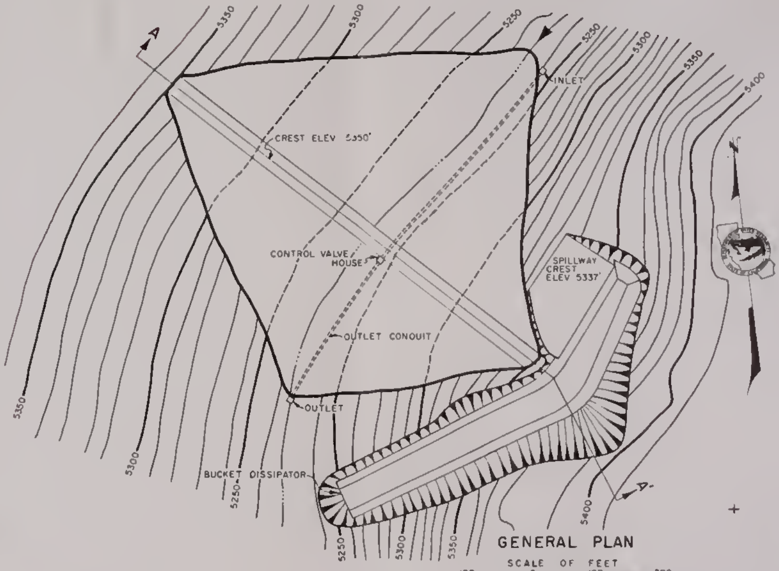
DRAWING NO WR-122	SHEET
FILE NO.	
DISTRICT	



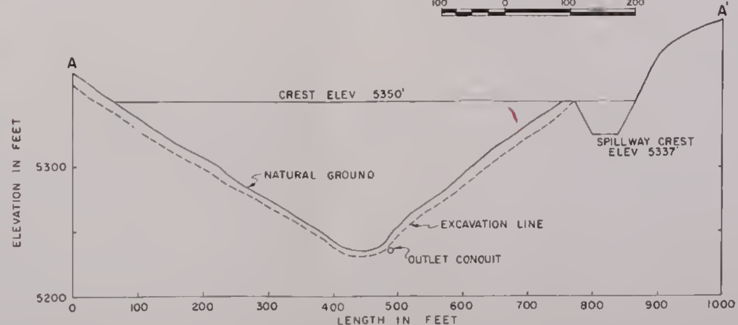
LOCATION MAP



SECTION OF DAM



GENERAL PLAN

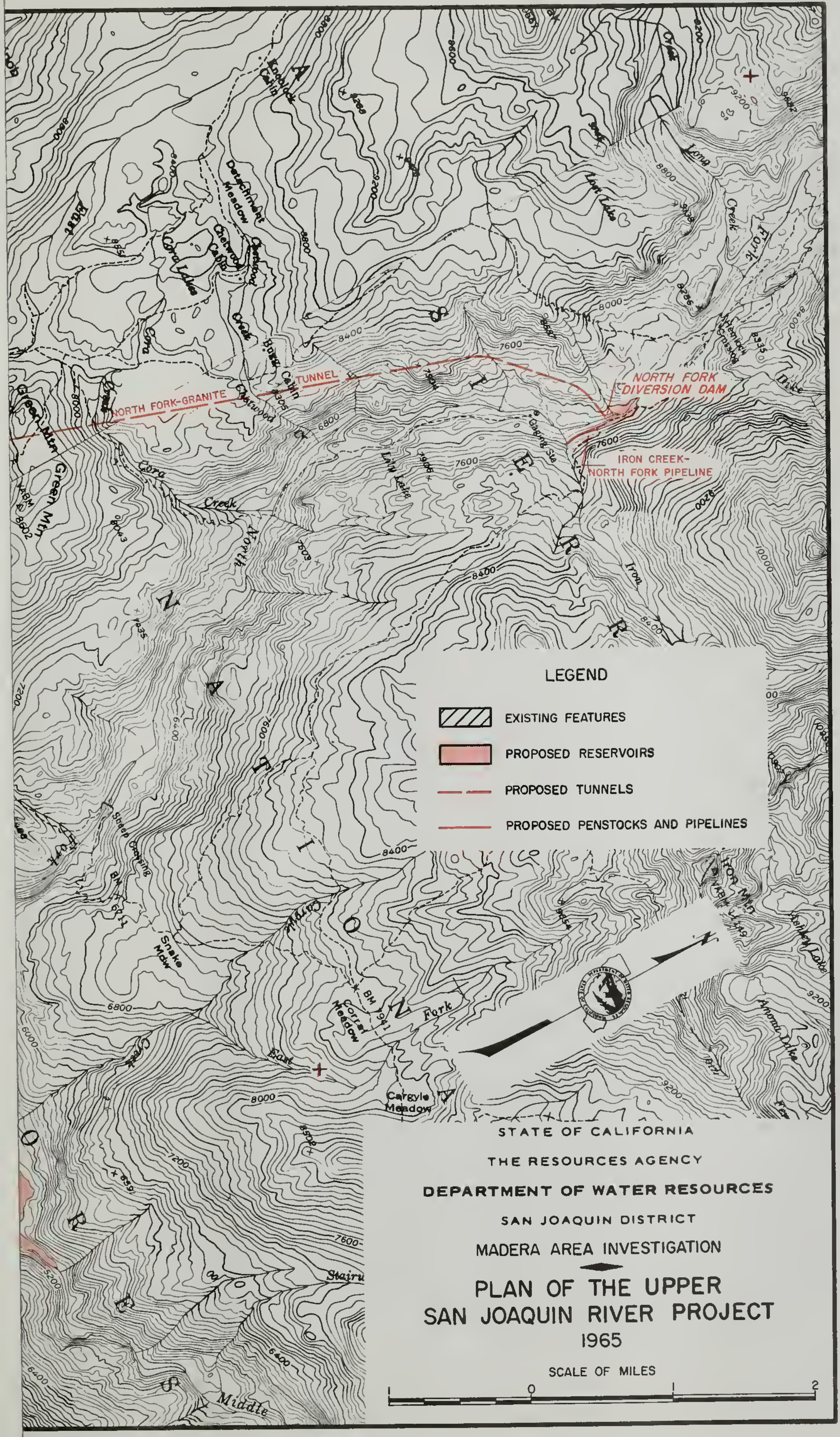


SECTION A-A'

LEGEND

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

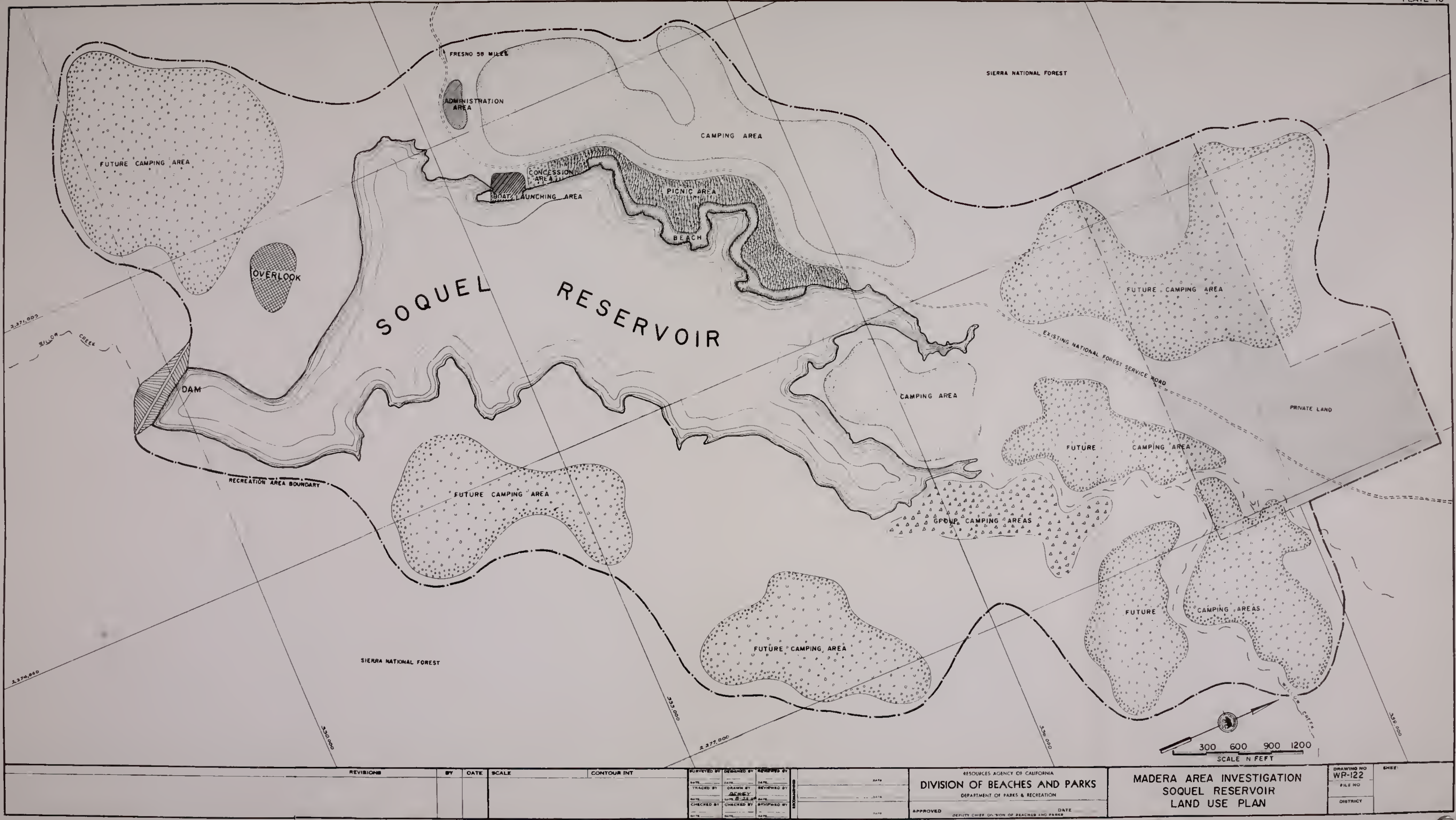
SOQUEL DAM ON NORTH FORK WILLOW CREEK
1965

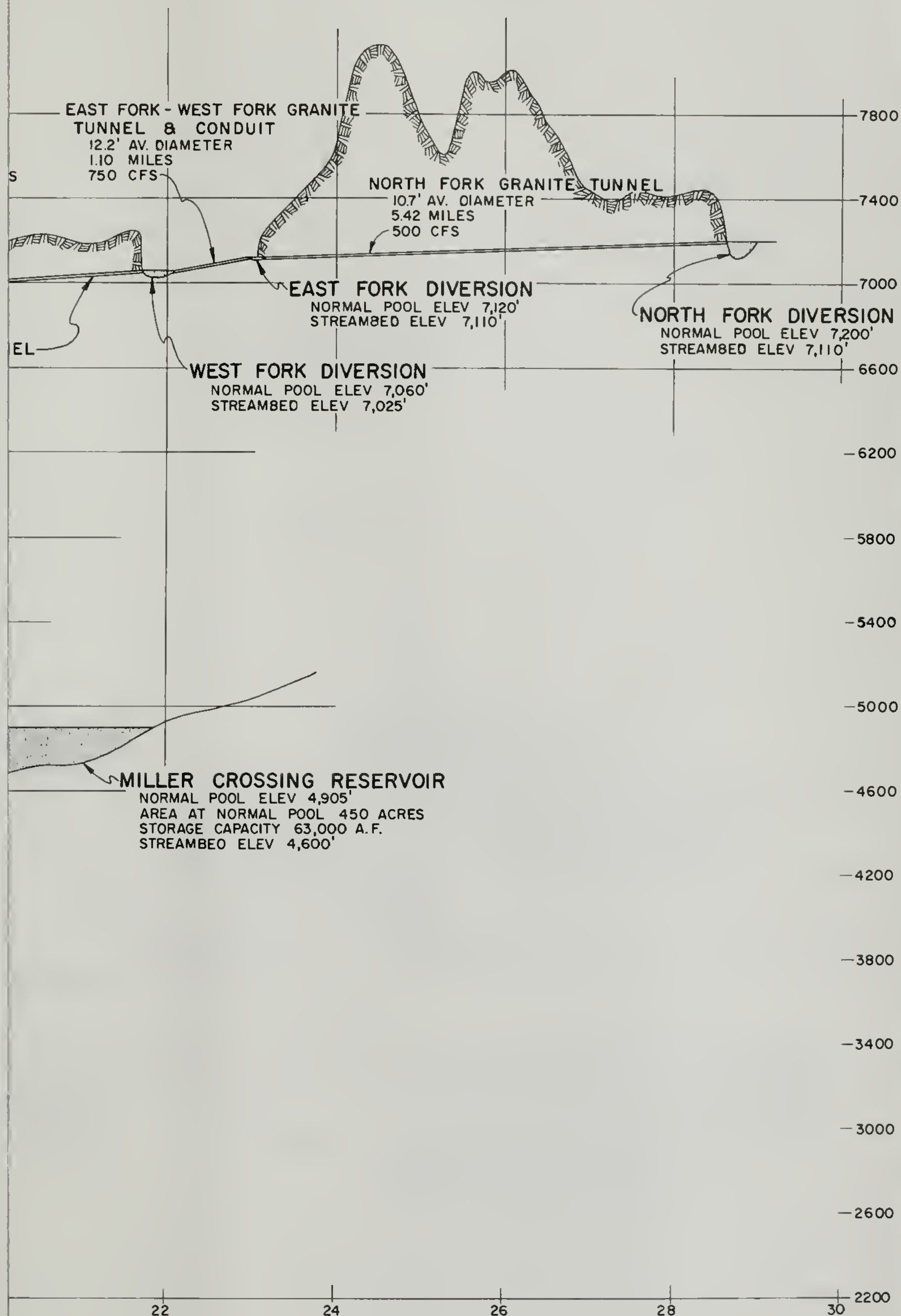


STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

PLAN OF THE UPPER SAN JOAQUIN RIVER PROJECT
1965

SCALE OF MILES
1 0 1 2


FRESNO 58 MILES
ADMINISTRATION AREA
SIERRA NATIONAL FOREST
CAMPING AREA
FUTURE CAMPING AREA
CONCESSION AREA
BOAT LAUNCHING AREA
PICNIC AREA
BEACH
OVERLOOK
SOQUEL RESERVOIR
DAM
WILLOW CREEK
FUTURE CAMPING AREA
EXISTING NATIONAL FOREST SERVICE ROAD
CAMPING AREA
PRIVATE LAND
FUTURE CAMPING AREA
RECREATION AREA BOUNDARY
FUTURE CAMPING AREA
GROUP CAMPING AREAS
FUTURE CAMPING AREAS
FUTURE CAMPING AREA
SIERRA NATIONAL FOREST
300 600 900 1200
SCALE IN FEET
REVISIONS
BY
DATE
SCALE
CONTOUR INT
RESOURCES AGENCY OF CALIFORNIA
DIVISION OF BEACHES AND PARKS
DEPARTMENT OF PARKS & RECREATION
APPROVED
DATE
DEPUTY CHIEF DIVISION OF BEACHES AND PARKS
MADERA AREA INVESTIGATION
SOQUEL RESERVOIR
LAND USE PLAN
DRAWING NO
WP-122
FILE NO
DISTRICT
SHEET

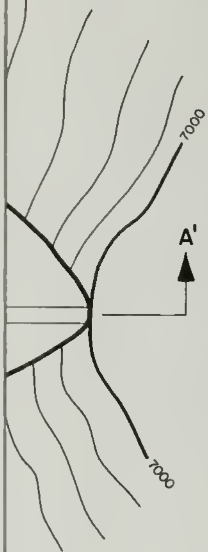


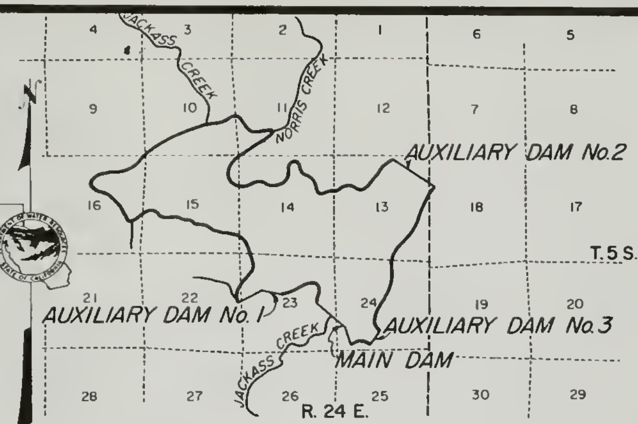
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

PROFILE
UPPER SAN JOAQUIN RIVER
PROJECT
1965

PLATE 19


JACKASS MEADOW RESERVOIR
CHIQUITO RESERVOIR
MAMMOTH POOL RESERVOIR
FORKS RESERVOIR
MILLER CROSSING RESERVOIR
FORKS POWERHOUSE
FORKS TUNNEL
SQUAW DOME POWERHOUSE
LOWER GRANITE CREEK DIVERSION
MILLER-SQUAW DOME TUNNEL
JACKASS-SQUAW DOME PIPELINE AND TUNNEL
GRANITE-JACKASS TUNNEL
W FORK GRANITE DIVERSION DAM
E FORK-W FORK GRANITE PIPELINE AND TUNNEL
E FORK GRANITE DIVERSION DAM
NORTH FORK-GRANITE TUNNEL
NORTH FORK DIVERSION DAM
IRON CREEK-NORTH FORK PIPELINE
LEGEND
EXISTING FEATURES
PROPOSED RESERVOIRS
PROPOSED TUNNELS
PROPOSED PENSTOCKS AND PIPELINES
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
PLAN OF THE UPPER
SAN JOAQUIN RIVER PROJECT
1965
SCALE OF MILES

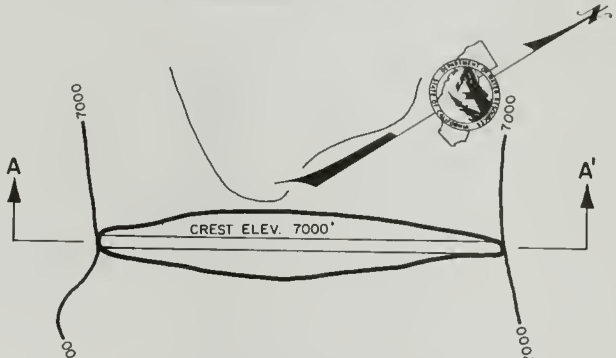




LOCATION MAP

SCALE OF MILES

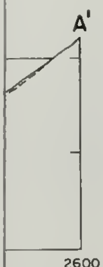
1 0 2

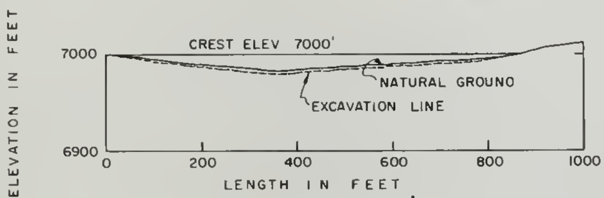


GENERAL PLAN

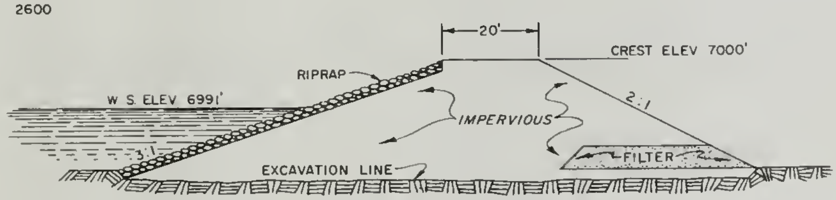
SCALE OF FEET

200 0 200 400





SECTION A-A'



SECTION OF DAM

SCALE OF FEET

20 0 20 40

AUXILIARY DAM No. 3

STATE OF CALIFORNIA

THE RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES

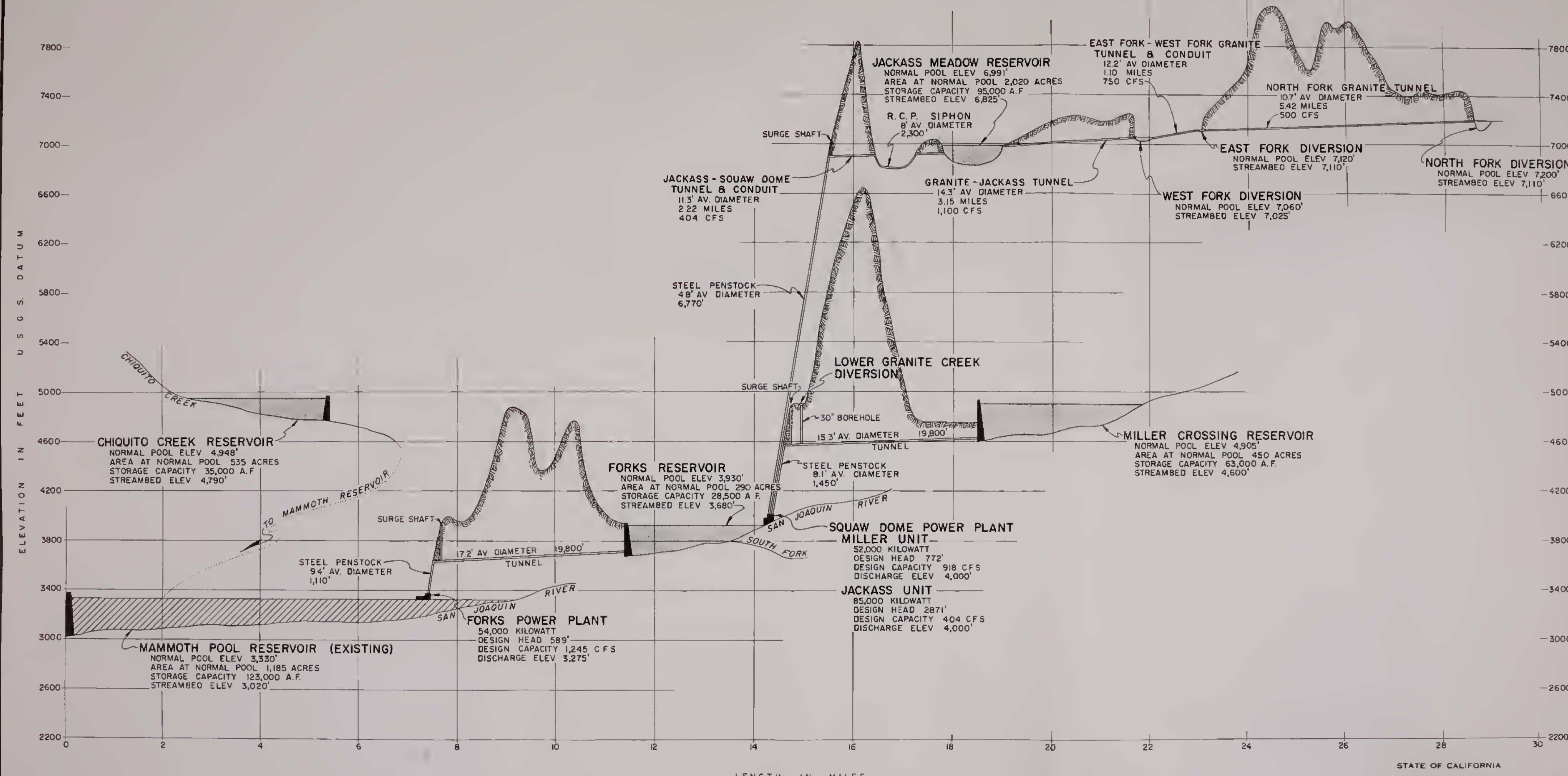
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

No. 2

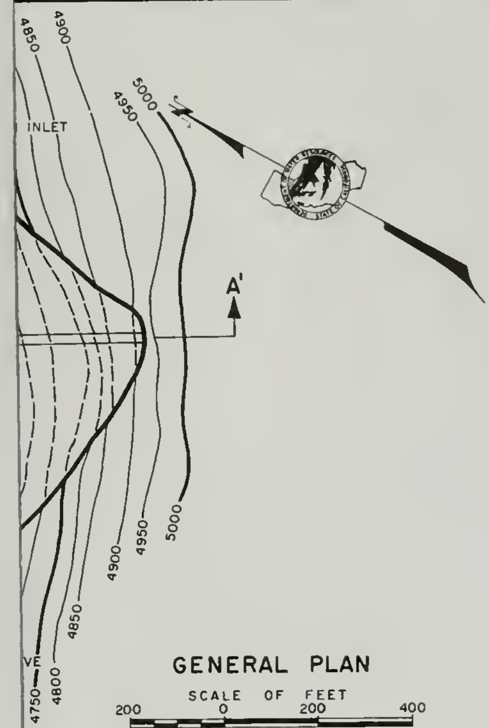
JACKASS MEADOW DAM ON JACKASS CREEK

1965



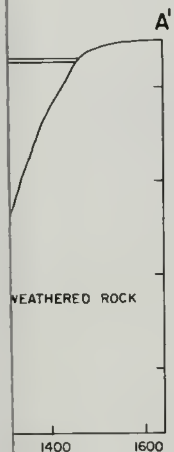
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION

PROFILE
UPPER SAN JOAQUIN RIVER PROJECT
1965



GENERAL PLAN

SCALE OF FEET
200 0 200 400



ER CROSSING DAM

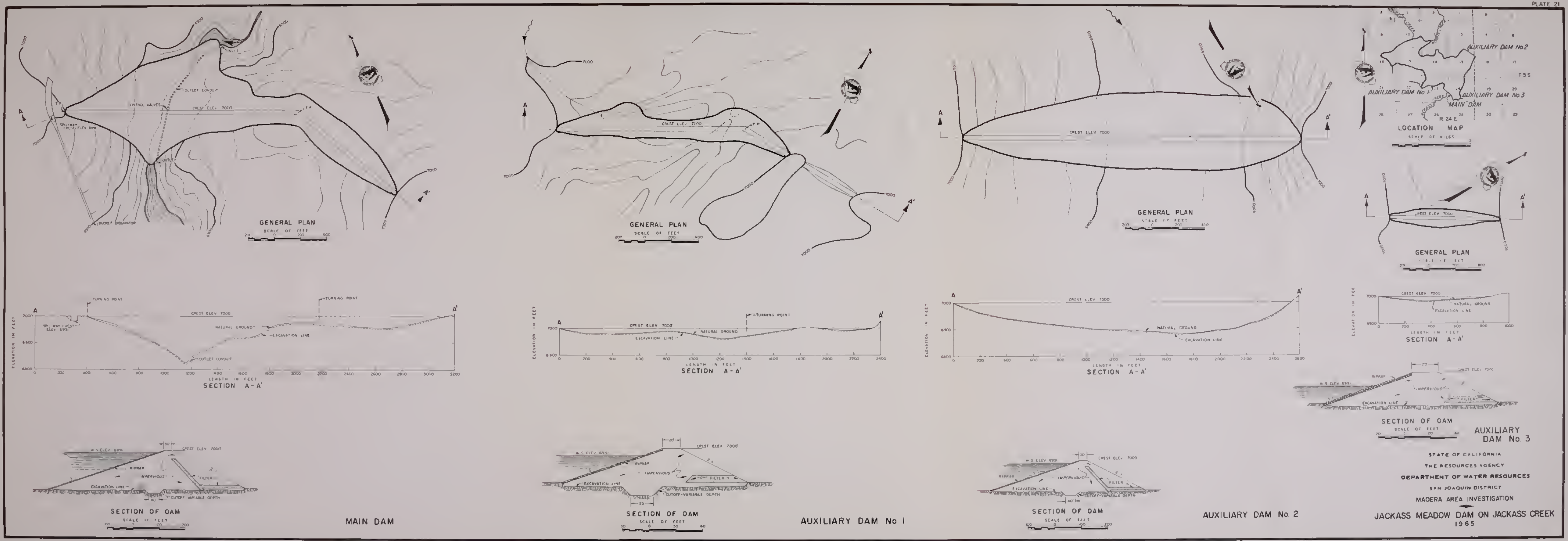
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

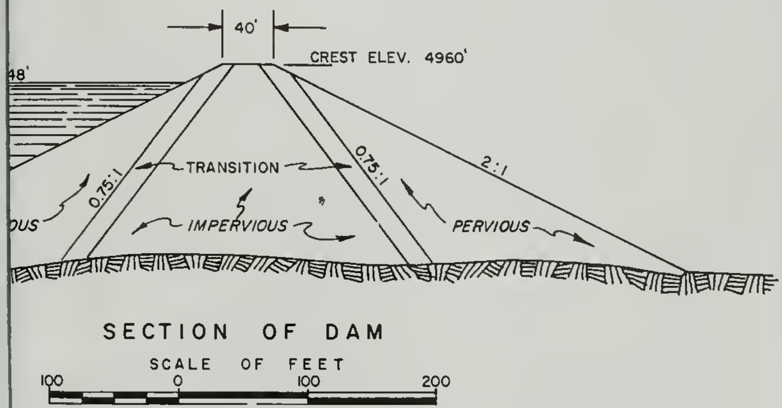
MADERA AREA INVESTIGATION

FORKS & MILLER CROSSING DAMS

1965

PLATE 21


GENERAL PLAN
SCALE OF FEET
SECTION A-A'
LENGTH IN FEET
ELEVATION IN FEET
CREST ELEV 7000
NATURAL GROUND
EXCAVATION LINE
TURNING POINT
OUTLET CONDUIT
SPILLWAY CREST ELEV 6991
SECTION OF DAM
RIPRAP
IMPERVIOUS
FILTER
CUTOFF-VARIABLE DEPTH
MAIN DAM
AUXILIARY DAM No 1
AUXILIARY DAM No. 2
AUXILIARY DAM No. 3
LOCATION MAP
SCALE OF MILES
AUXILIARY DAM No 2
AUXILIARY DAM No 1
AUXILIARY DAM No 3
MAIN DAM
T5S
R 24 E
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT
MADERA AREA INVESTIGATION
JACKASS MEADOW DAM ON JACKASS CREEK
1965



SECTION OF DAM

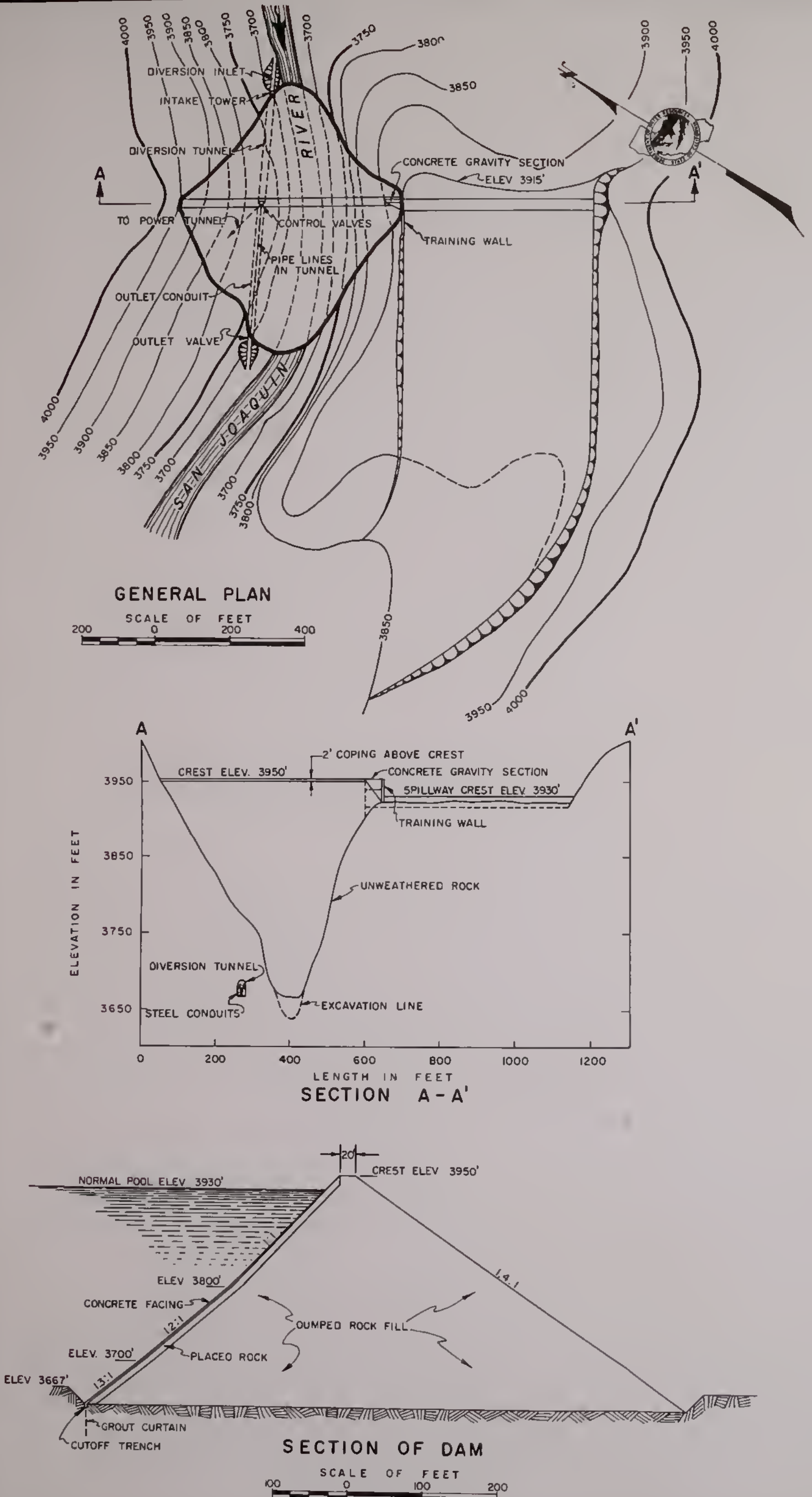
SCALE OF FEET

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

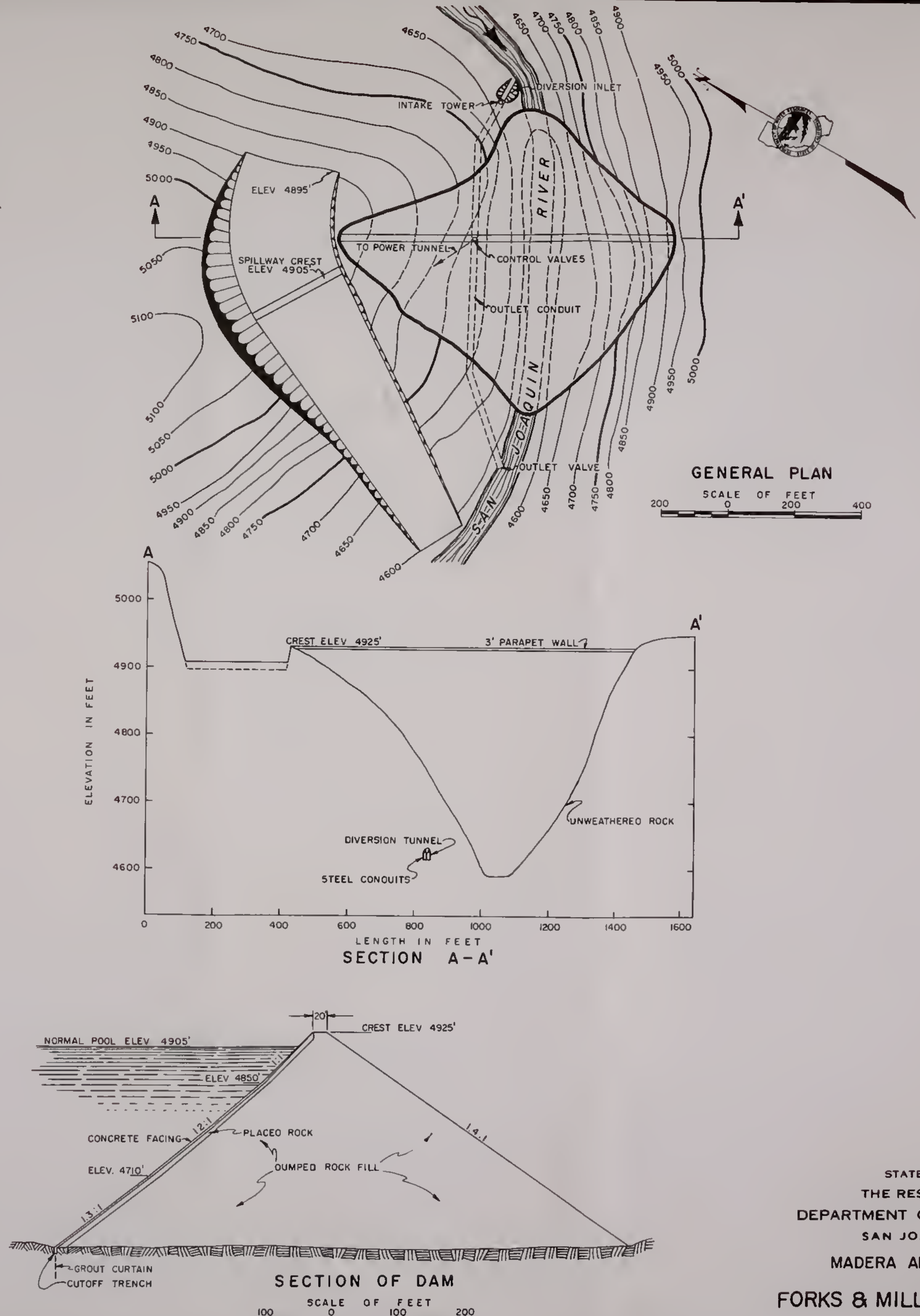
MADERA AREA INVESTIGATION

CHIQUITO DAM ON CHIQUITO CREEK

1965



FORKS DAM



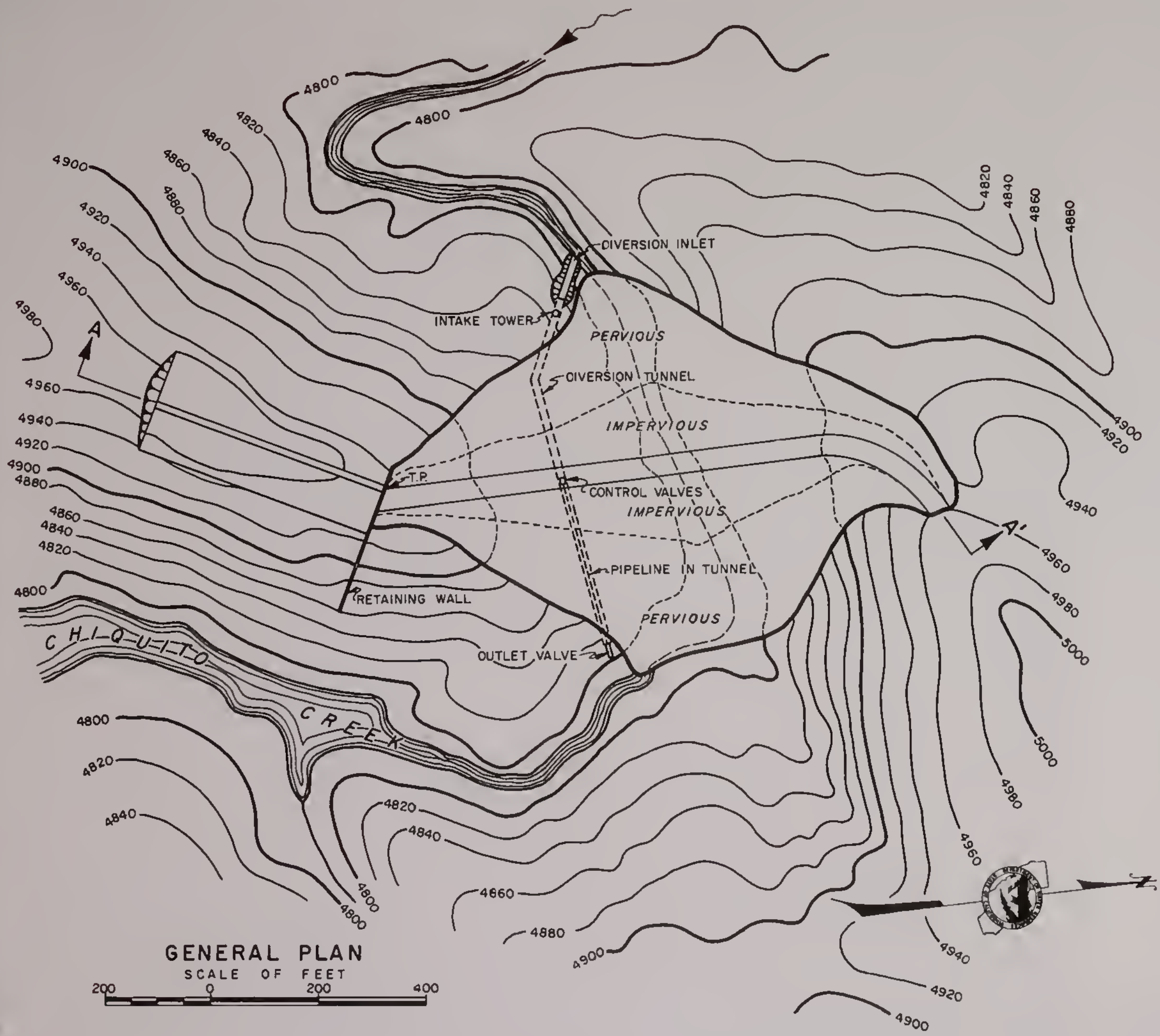
MILLER CROSSING DAM

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

FORKS & MILLER CROSSING DAMS

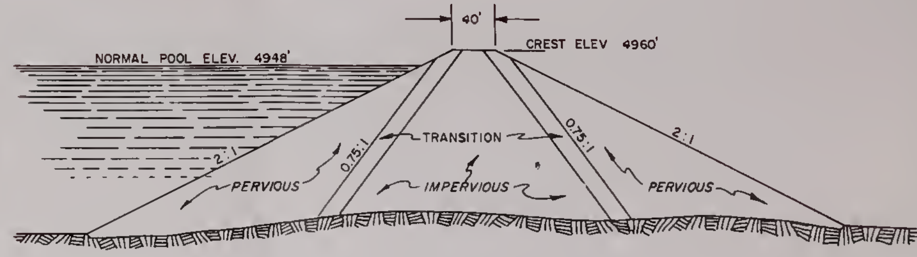
1965



GENERAL PLAN

SCALE OF FEET

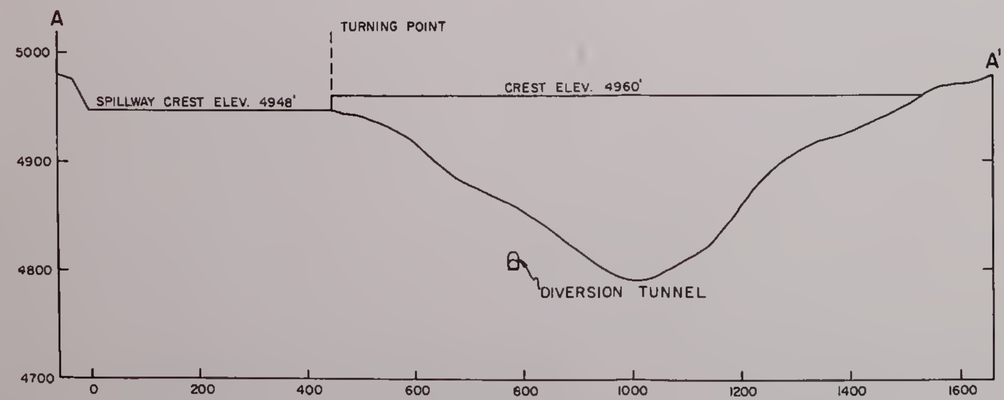
200 0 200 400



SECTION OF DAM

SCALE OF FEET

100 0 100 200



SECTION A – A'

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
SAN JOAQUIN DISTRICT

MADERA AREA INVESTIGATION

CHIQUITO DAM ON CHIQUITO CREEK
1965